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REPORT

ON THE

DESTRUCTION OF TOWN REFUSE

BY

THOMAS CODRINGTON, M. INST. C. E.,

ENGINEERING INSPECTOR OF THE LOCAL GOVERNMENT BOARD.

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REPORT

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ENGINEERING INSPECTOR OF THE LOCAL GOVERNMENT BOARD.

To the Right Honourable
CHARLES THOMSON RITCHIE, M.P.,
The President of the Local Government Board.

SIR,

IN carrying out the Board's instructions, communicated to me by Sir Robert Rawlinson, to report on the different methods in use for destroying town refuse, I have during the past twelve months visited all those towns in Great Britain where works for the purpose have been established. Assistance in the inquiry has been willingly given by the borough engineers and surveyors, and the superintendents of the Sanitary Departments, and to them is due much of the information which I have the honour to lay before the Board in the present report.

Town refuse, consisting of the contents of ash-pits and dust-bins, market and trade refuse, and the sweepings of paved streets, includes materials which, when sorted out and separated, may yield a small return, or can be utilized in some way. But this part of the refuse has, from various causes, lost much of whatever value it formerly had, and the sanitary objections to the handling of an offensive material for the sake of a small gain are now more generally recognised. It has also become more and more difficult to get rid of that part of the refuse which is absolutely worthless. The practice of filling up pits, quarries, and hollows with materials containing offensive and putrescible matters, sometimes afterwards to be built on, is now properly condemned on sanitary grounds, and town authorities, when places for deposit within their own boundaries are no longer available, find neighbouring authorities more and more averse to allow refuse to be accumulated within their districts. The disposal of town refuse has thus become almost everywhere a troublesome question.

Composition of town refuse.

In towns in which waterclosets are general, the house refuse consists of cinders and ashes mixed with vegetable and animal waste, broken glass and crockery, and the rubbish of all sorts that finds its way into the dust-bin or ash-pit, including often trade refuse and garden refuse in greater or less proportion. In some towns the trade-refuse, market-garbage, and the sweepings of paved streets amount to as much as the house-refuse. The trade refuse consists of coarse paper, straw, shavings, broken stoneware and glass, engine ashes, brick rubbish, spoilt fruit, fish, and tinned provisions, &c. Market refuse is strictly the animal and vegetable matters removed from markets, but it is often mixed with other refuse, and, generally speaking, the different sorts of town refuse can only be roughly classified.

The annual reports of Mr. G. Weston, the Surveyor of the parish of Paddington, give the constituents of the dust collected from a population of about 112,000, and they may be taken as giving the fair average composition of London town refuse. In 1886, 20,600 tons of "dust" were collected, and the materials, when sorted out, were in the following proportions per 1,000 tons. Other years give much the same results.

London Refuse.	Per 1,000 Tons.
Ashes - - - - - -	526
Breeze (cinders) - - - -	288
Soft core (animal and vegetable refuse) - -	142
Hard core (broken pottery, &c.) - -	29
Coal - - - - - -	1½
Bones - - - - -	2½
Rags - - - - - -	4¼
Old iron - - - - -	3½
Old metals (brass, pewter, &c.) - - -	¼
White glass - - - - -	¾
Black glass - - - - -	2¼
Tons - -	1,000

In the dust yards in and around the metropolis the ashes, and breeze or cinders, are sifted out and sold to brickmakers, and from the residue all that is saleable is picked out; leaving the hard core and soft core to be got rid of, which is generally accomplished by carting or barging or sending it away by railway. Some of the hard core is used for road foundations, and the soft core is sometimes mixed with garbage and street sweepings and sent away as farm manure.

Where the privy-and-ash-pit system, or the pail-system, is in use, the finer ashes are mixed with the excreta, either in the closet or subsequently, to make a portable manure, and the contents of the ashpits are generally more or less fouled with excrementitious matter. In Manchester, where pail-closets prevail, of 1,000 tons collected from the closets and ash-pits in 1880, the constituent parts seem to have been as follows*:—

Manchester Refuse.	Per 1,000 Tons.
Ashes and excreta in pails - - -	645
Dust and cinders - - - -	345½
Fish and bones - - - -	1½
Dogs, cats, hens, rabbits, &c. - -	½
Boots, rags, hats, paper, &c. - - -	½
Vegetable refuse - - - -	½
Glass, pottery, bricks, &c. - - -	6
Old iron and tin ware - - -	½
Tons - - -	1,000

For every 1,000 tons collected from the closets and ashpits, about 290 tons of slaughter-house, market, and shop refuse, and street sweepings were besides collected, the whole being about 250,000 tons.

There is considerable difference in the nature of town refuse under different circumstances. Where coal is cheap a larger proportion of cinders and unburned fuel might be expected, but this is not always the case. People who burn their own coal are generally less wasteful than a higher class population at the mercy of servants, and this is often shown in different quarters of the same town. The superintendents from several large towns who visited with me a dust yard near the west end of London expressed surprise at the large quantity of cinders and coal in the refuse. In Glasgow, on the other hand, there is said to be most cinders in the ashes from the poorer classes of the city. In summer the quantity of vegetable refuse is larger, and there is less of cinders and ashes, so that the refuse is damper than in the winter. Where uncovered ashpits are allowed, the contents get sodden with wet in rainy weather, especially if they are not cleared frequently.

Weight

A cubic yard of ordinary refuse weighs from 12¼ to 15 cwt. Shop refuse is lighter, sometimes weighing as little as 7¼ cwt. per cubic yard. A load, by which refuse is often reckoned, varies in weight from 15 cwt. to 1½ tons.

and quantity of refuse.

The quantity of town refuse collected appears to range from 200 to 300 tons per year per 1,000 of population, and of this whatever cannot be utilized has to be got rid of.

Disposal of refuse.

Some towns, whose situation admits of it, send their refuse to sea, and deposit it in deep water. Liverpool employs two steam hopper barges of 350 tons burden each, and sends yearly about 89,000 tons of refuse, not to be otherwise got rid of, 11 miles outside the bar of the Mersey. Dublin, in 1885, sent about 36,000 tons of unsalcable refuse to sea in a similar manner, and Sunderland and other sea-side towns adopt the same course.

---

[*] Detailed statement of refuse collected for year ending August 31, 1880, by Mr. Henry Whiley.

To burn rubbish is an obvious way of getting rid of it, and burning town refuse in heaps in the open air is an old practice. It must always, from the imperfect combustion of an offensive material, be attended with nuisance, but it is still continued, even in the neighbourhood of the metropolis.

Paddington.

An attempt to burn house-refuse in a closed furnace was made by Messrs. Meade & Co., dust contractors, at Paddington, about 1870. Two furnaces, each 10 feet long by 5 ft. 6 ins. wide, having a fire-grate of that area, were built, with a chimney shaft 102 feet high, but they were soon pulled down, as they failed to burn the refuse for want of draught, which was attributed to their being below the level of the ground. Judging from a drawing, however, the great defect was want of sufficient area in the flue, which was only 1 ft. 9ins. square for 110 square feet of fire-grate. Some few years later, furnaces for the same purpose were erected at Manchester, under the superintendence of Mr. H. Whiley, of the Health Department. The first furnace consisted of a combustion-chamber 8 feet long and 5 feet wide internally, covered in with an arch 6 feet high. There were two furnace mouths 4 feet above the yard level, from which the bottom, consisting of a fire-grate 5 feet long and a hearth 3 feet long, sloped upwards 1 in 8, to the back of the furnace. A flue, 3 ft. 6 ins. wide and 1 ft. 6 ins. high, rose at a steep angle from the back of the hearth for 8 feet, and then turned at right angles to the chimney. The top of the flue was of fire-brick slabs, and over it was the passage by which refuse was fed into the furnace by an opening over the upper end of the flue. The intention was, that in passing downwards over the heated flue-top, the refuse should be dried, but this was found to be so imperfectly effected that this form of furnace was not continued.

Manchester.

In another furnace constructed about the same time the combustion-chamber is 10 feet square and 12 feet high to the crown of the arch. From the dead-plate of a furnace mouth 4 feet wide and 2 ft. 6 ins. above the yard level, fire-bars slightly inclined extend backwards for 5 feet, beyond which a sloping hearth rises to the back of the furnace. The passage to the flue is downwards through a sort of chimney in the back of the furnace, rising to 8 feet above the level of the fire-bars. The refuse is thrown in through a door at the side on to the sloping hearth. This furnace is still in use for burning foul straw, mattresses, and other bulky materials.

Plate I.

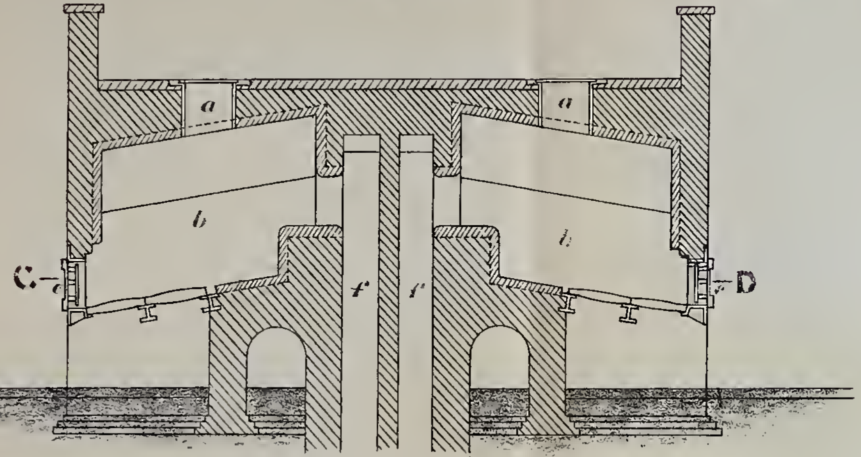
Soon after, furnaces similar to those which are shown on Plate I. were erected, and the plan has been followed ever since. The cells or combustion-chambers are arranged in groups of four, back to back; they are each 8 ft. 6 in. long, 4 ft. 3 in. wide, and 6 ft. 3 in. high from the fire-bars to the crown of the arch. The bottom slopes upwards, 1 in 6, from the furnace doors, and consists of a length of 5 feet of fire-bars and 3 feet of hearth, beyond which is a step or bridge 2 feet high, over which the products of combustion pass into a descending flue to an underground flue leading to the chimney. The furnace is made high

PLATE I.

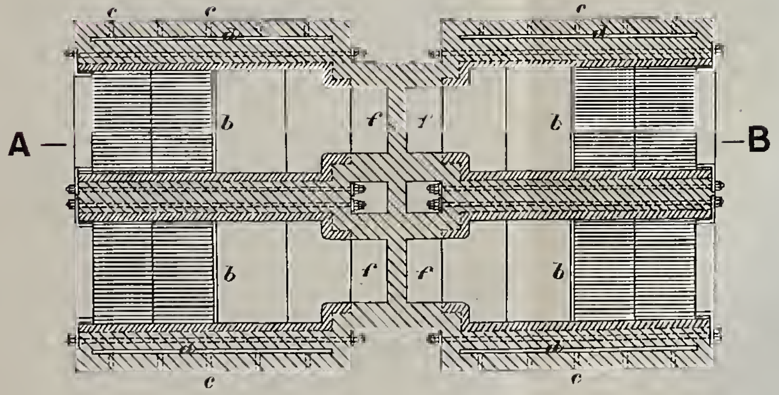
MANCHESTER,
DESTRUCTOR FURNACE,
1877-1887.

a. a. Feed Holes.
b. b. Furnaces.
c. c. Cold Air Inlets.
d. d. Air Spaces.
e. e. Fire Doors.
f. f. Flues.

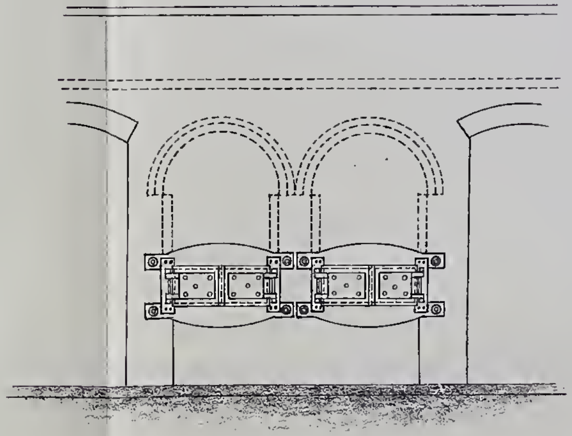
SECTION AT A.B.



PLAN AT C.D.



ELEVATION.



Scale 8 Feet to an Inch.

DANGERFIELD, LITH. 22. BEDFORD ST COVENT GARDEN

to prevent burning the arch, and the fire-brick lining at the sides is independent of the walls. The refuse is fed into an opening over the middle of the furnace, and thus into the hottest part of the fire, without any attempt at previous drying.

The furnaces shown on Plate I. have been in use at the Water Street depôt since 1877. Two blocks of four furnaces were in operation in 1886, and another similar block has lately been added, making in all 12 furnaces. An inclined road leads to a platform level with the top, on to which the refuse is tipped, and which is covered by an iron shed roof.

The material burned consists of what remains of the ashpit refuse after the fine ashes and part of the coarser cinders have been separated by screening, the former to be mixed with pail-contents, and the latter to be burned under two 40 horse-power Lancashire boilers, and raise steam for driving the machinery. At the Holt Town Works there are four of these furnaces which consume such rubbish as cannot be burned under the boilers (of which there are twelve), with the aid of a little coal, for evaporating and concentrating excreta, and to work the necessary machinery. Great care is taken to feed the furnaces and to remove the clinkers, which are produced by burning, with regularity. A table is painted up at each furnace, setting out the times at which it is to be clinkered, at intervals of 1½ hours day and night, and so arranged that two furnaces are clinkered in rotation every quarter of an hour. The furnace men attend to the feeding as well as to the clinkering, and both operations go on with the same regularity. For the eight furnaces at Water Street four men are employed by day and four by night besides a man by day and one by night to assist at feeding. The boiler furnaces are fed and clinkered with the same regularity every 1¼ hour, so that of the eight furnaces and four boiler furnaces in use at Water Street one-half to two-thirds are always burning with hot clear fires, the hot gases from which mix in the main flue with those from the newly charged furnaces and effectually burn them. The temperature in the furnaces was found by Mr. Darley, Smoke Inspector of Leeds, to average 625° Fahr. Very little smoke is emitted from the chimney, which is 138 feet high.

A trial made with the eight furnaces at Water Street showed that they consumed 226 tons of refuse in a week of 132 hours, or 5½ days, being at the rate of 28½ tons per furnace per week, or 5 tons 2 cwt. in 24 hours, the grate-area being 21¼ square feet. The clinker and ashes produced were nearly one-half by weight of the material burned. The clinker is used for making mortar, for which purpose there are five mortar mills with edge-runners, and the fine dust from the flues is mixed with carbolic acid and made into disinfecting powder.

At Birmingham a four-cell Fryer's Destructor was erected at the Shadwell Street wharf in 1877, with concretors for concentrating excreta and a carbonizer for vegetable refuse. In consequence of complaints from the General Hospital, which is only **Birmingham.**

separated from the works by a canal, the use, first of the concretors, then of the carbonizer, and finally of the destructor, was discontinued. Subsequently, alterations were made in the furnaces of the destructor, and feed-openings were made in the middle over the upper end of the fire-grate. So altered, the furnaces are now worked as much as possible by night, and burn 5,600 tons of refuse a year, after the fine ashes have been sifted out for mixing with excreta for manure, without complaint from the hospital.

At the Montague Street wharf the contents of the ash-tubs are carried by an elevator to a rotating screen, by which the fine ashes are separated and passed through a hopper and pipe to a pug-mill, where they are mixed with excreta from the pails. The mixture is delivered into barges and sold for manure. The greater part of the cinders and the rubbish is burned under steam-boilers for drying excreta, and the residue, including the more offensive refuse, is burned in furnaces designed by Mr. J. Wilkinson, and shown in Plate II. They are four in number, each 7 ft. 4 in. long and 5 ft. 4 in. wide; the fire-grate occupies the whole of the bottom, and rises with an inclination of 1 in 10 towards the back. The covering arch is 3 ft. 3 in. high at the fire-door and has a feed-hole in the top towards the back of the furnace. The latter consists of a pigeon-holed wall of fire-brick, 9 inches thick, presenting a large heated surface to the vapours as they pass off. Beyond is a dust-chamber, 1 ft. 6 in. wide, and extending to the level of the ground, with an opening into the ashpit, closed by loose bricks, which are removed when the dust is cleared out. An opening, fitted with a damper, leads from the dust-chamber to the flue, which is on a level with the furnace, and is connected with the chimney by a descending flue. Plate II.

The gases from the drying excreta are extracted by blowers and passed into the furnaces through pipes, entering on each side of the fire-door. Gases which had a most offensive smell on entering the furnace, when taken from the base of the chimney were found to be odourless.

The furnaces are fed principally from the top, though sometimes by the fire-door as well. The fire is pushed to one side of the furnace and to the back, exposing the clinker, which is lifted from the fire-bars and raked out. The fire is then spread evenly, and a fresh charge is thrown in upon it. The furnaces are banked on Saturday afternoon and left till midnight on Sunday, thus burning continuously about 132 hours a week. They are said to be capable each of burning six tons of ordinary refuse in 12 hours.

The chimney is 260 feet high, serving for 15 boilers as well as the four furnaces. A little smoke of a light colour is all that is visible at the chimney-top. The clinker obtained from the burned refuse is used for making mortar, concrete paving, coping, &c., as well as for street foundations.

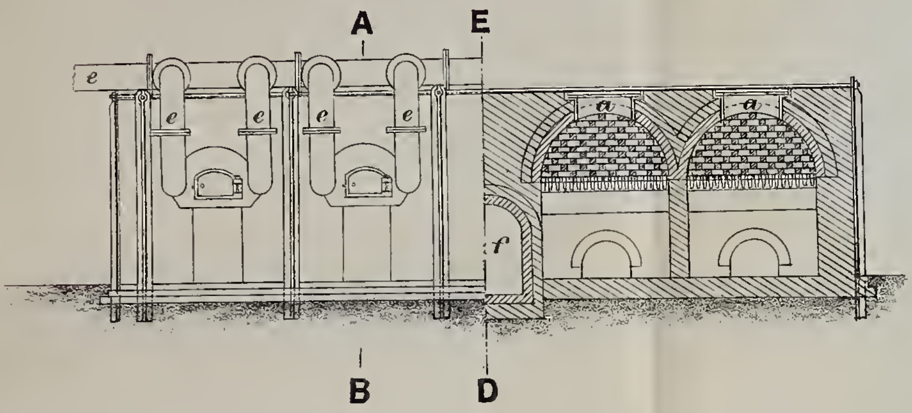
The cost of the furnaces was about 120*l.* each, and that of the chimney about 1,000*l.* One man by day and one by night work the four furnaces, and the labour costs about 2*l.* 12*s.* per week.

PLATE 2.

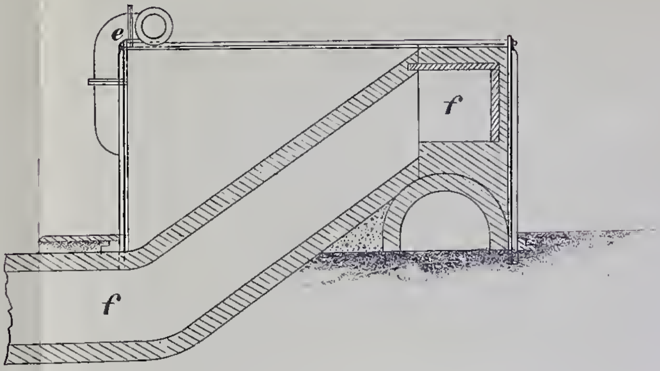
BIRMINGHAM.

MUFFLE FURNACES AT MONTAGUE S^T WHARF.

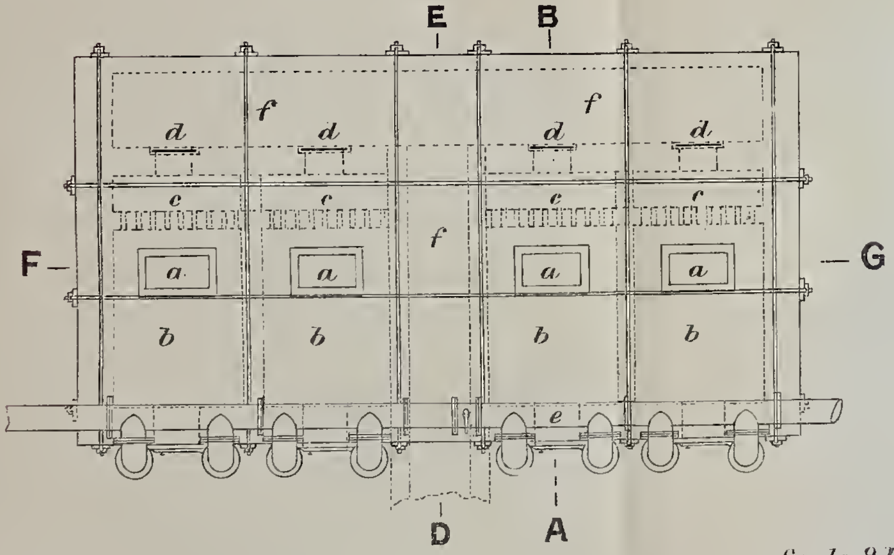
HALF ELEVATION. HALF SECTION ON F.G.



SECTION ON D.E.

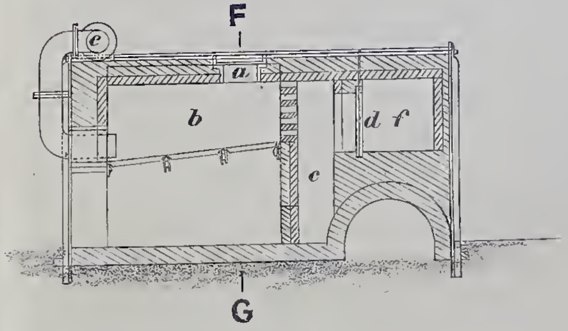


PLAN AT TOP.



a. a. Feed Holes.
b. b. Furnaces.
c. c. Dust Chamber.
d. d. Dampers.
e. e. Foul Air Main.
f. f. Flues.

SECTION ON A.B.



Scale 8 Feet to an Inch.

DANGERFIELD, LITH. 22, BEDFORD S^T COVENT GARDEN.

Blackpool.

Furnaces on the model of those at Birmingham were constructed at Blackpool, but the length was increased from 7 ft. 6 ins. to 12 ft. 3 ins. This rendered necessary the use of long and heavy bars for lifting the clinker, and adds considerably to the labour of clinkering. The pigeon-holed wall fell down into the dust-chamber behind, probably from blows from the heavy bars, which also damaged the fire-brick lining originally built. Extensive repairs became necessary, and in carrying them out alterations were made. The pigeon-holed wall was replaced by a solid wall 1 ft. 6 ins. high, and the dust-chamber behind was filled up. A greater inclination was given to the fire-grate to facilitate clinkering, and the furnaces were re-lined with fire-brick. The furnaces and firing-floor are covered by a timber shed (which has caught fire), and a raised road leads to a tipping place 2 ft. higher than top of the furnace. The openings by which the furnaces are fed are 2 ft. 6 ins. square, with iron covers, and about a ton is put into one furnace at a time for a charge.

The whole of the refuse of Blackpool, including some privy-and-ash-pit contents, is burned in four of these furnaces. The population is 17,000, increasing to 80,000 in the summer, and to 100,000 by day sometimes. The amount burned is estimated at about 7,000 tons a year, or about 34 tons per cell per week on the average, but more in the summer and autumn, when the four furnaces are insufficient, and the refuse accumulates on the furnace top. The clinker amounts to about one-third of the refuse burned. The burning goes on night and day throughout the week, two men being employed by day and two by night. No use is made of the heat. The chimney is 120 feet high, and emits a slight smoke. In some weathers, with a south-west wind, a smell from the chimney is perceived in the town.

Glasgow.

The burning of refuse forms part of the system of cleansing and scavenging carried out in Glasgow under the able superintendence of Mr. John Young. The pail-system is here in operation for the lesser half of a population of 543,000, and the pail-contents of the whole city, with the ashpit and shop-refuse and the street sweepings, are collected and dealt with at two dispatch stations, one for the north and one for the south of the city. The ashpit refuse is passed through double revolving conical screens, which separate the fine ashes from the cinders and deliver the rougher rubbish and garbage on to an endless web, which takes it to the top of the furnaces. The fine ashes pass to a pug-mill, where they are mixed with a regulated quantity of excreta from an air-tight tank, into which the pails are emptied, and the manure thus prepared is discharged into railway trucks and sent direct into the country. The cinders are burned under two Lancashire boilers, 7 feet in diameter and 36 feet long, and are more than enough to raise the necessary steam power for the works. The rougher rubbish is picked over on the endless web on its way to the furnaces, and old iron and tin, old boots, garbage, &c., and all that will not burn are taken out, so that what is eventually burned is principally paper and shop-refuse.

Plate III.

The furnaces at the Crawford Street Works, which are shown on Plate III., are two in number, each 12 feet wide, the whole width being occupied by the fire-grate, which is 7 feet long, and rises towards the back with an inclination of 1 in 7. At the front of the furnace the height of the covering arch is 4 ft. 3 ins. above the fire-bars. There are two furnace doors, 3 feet wide, to each furnace, and two outlets, each 4 feet wide, sloping upwards from the back of the fire-grate, and then turning downwards to the main flue. The ashpits are closed by doors, and the foul air is exhausted from the excreta-tank and mixing chamber by a fan, and forced into the back of the ashpit and through the fire. The two furnaces form a block 28 ft. 6 ins. by 15 ft. 8 ins. and 10 feet high, the top forming the bottom of a pit in the upper floor of the building, about 6 feet deep, into which the rubbish to be burned is delivered, and is fed into the furnaces through two openings over the upper end of the fire-grates. A large charge is put in when the fire is clear, and the feed-hole is closed by a cover. The clinker is withdrawn every two hours. The furnaces are banked up at about mid-day, by which time the rubbish collected in the previous night is nearly all burned, and at 11 p.m., when the refuse begins again to arrive, the fires are started with old baskets, &c. The quantity of refuse burned at the Crawford Street Works in 1886 was about 11,000 tons, an average of 210 tons per week, but in November as much as 396 tons per week were burned. About one-fourth by weight is left as clinker, which is conveyed to tips by rail.

At St. Rollox Works, constructed earlier, there are five furnaces of a similar character, all 6 ft. from back to front, but varying in width from 6 ft. to 12 ft. About the same quantity of refuse is burned as at Crawford Street. The chimney is 50 yards high, that at the Crawford Street Works being 80 yards. The main flues are cleared every two months of a fine dust, which at Crawford Street amounts to about 6 cubic yards. There are no complaints of dust or smell from the chimneys, which both emitted a light greenish yellow smoke. In the main flue at Crawford Street a grid with $\frac{3}{4}$ inch spaces, kept cold by water passing through it, has been fixed to catch charred paper, which at first escaped from the chimney-top.

In the furnaces which have now been described the attempts made in the early furnaces to dry the refuse before burning it were abandoned. The refuse is fed directly into the hottest part of the fire, and large grate area, with careful and systematic charging and clinkering, are depended upon for the destruction of smoke and offensive vapours.

In the class of furnaces now to be considered the idea of drying the refuse before it reaches the fire has been followed up with more or less success.

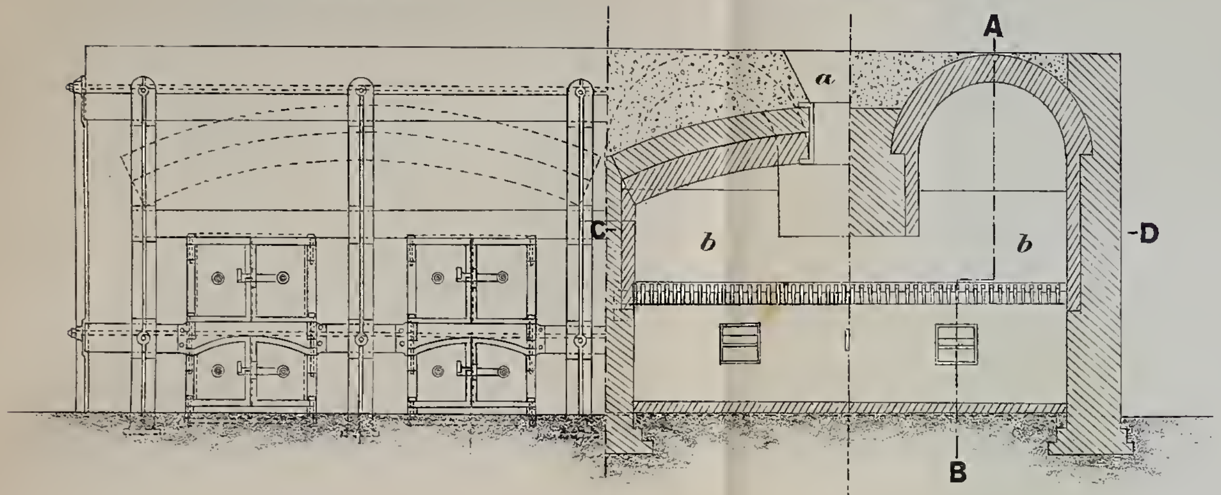
Fryer's Destructor. Plate IV.

Fryer's destructor, the general arrangement of which was patented by Mr. Alfred Fryer, of the firm of Manlove, Alliott, and Fryer, in 1877, is shown on Plate IV. It consists of a group of furnaces or cells, each internally about 9 ft. long and 5 ft. wide, covered by a fire-brick arch 3 ft. 6 in. high. The furnace has an

PLATE 3.

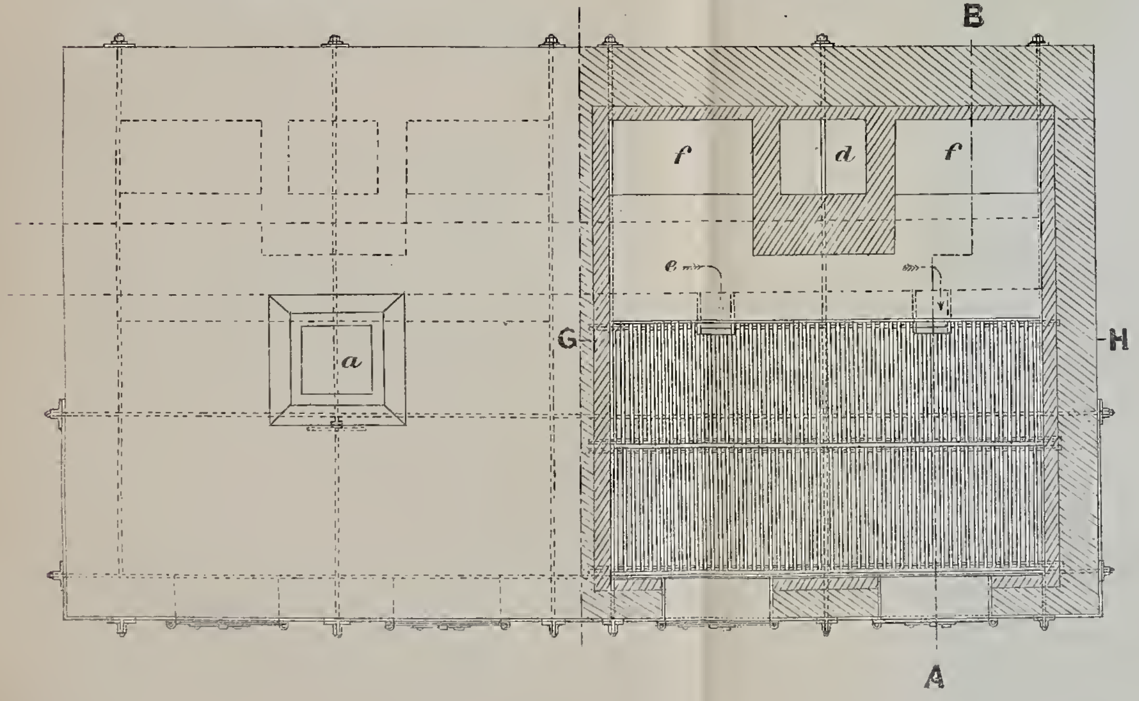
GLASGOW.
CRAWFORD ST WORKS.
RUBBISH FURNACE.

ELEVATION. **SECTION ON G.H.-I.K.**

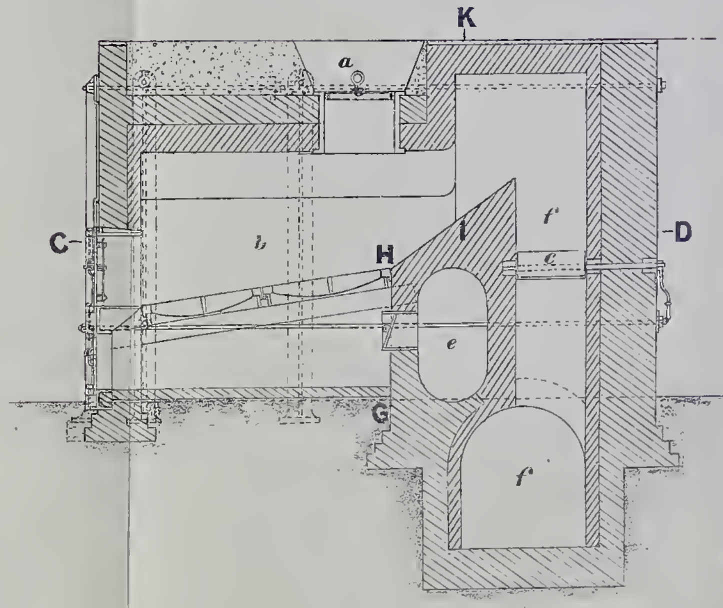


a. a.	*Feed Holes.*	
b. b.	*Furnace.*	
c. c.	*Damper.*	
d.	*Air Space.*	
e. e.	*Foul Air Flue.*	
f. f.	*Flues.*	

PLAN AT TOP. **PLAN AT C.D.**



CROSS SECTION ON A.B.



Scale 8 Feet to an Inch.

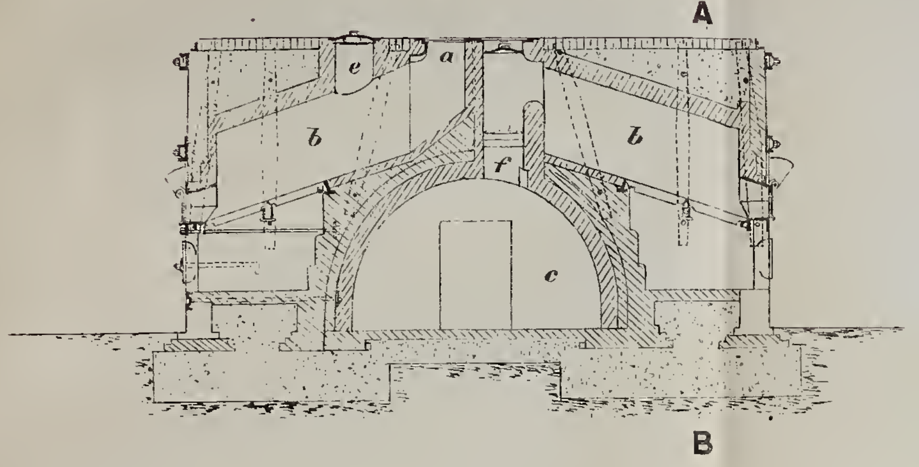
10 5 0 10 20 Feet.

GANGERFIELD LITH. 22, BEDFORD ST COVENT GARDEN 8.87.14597

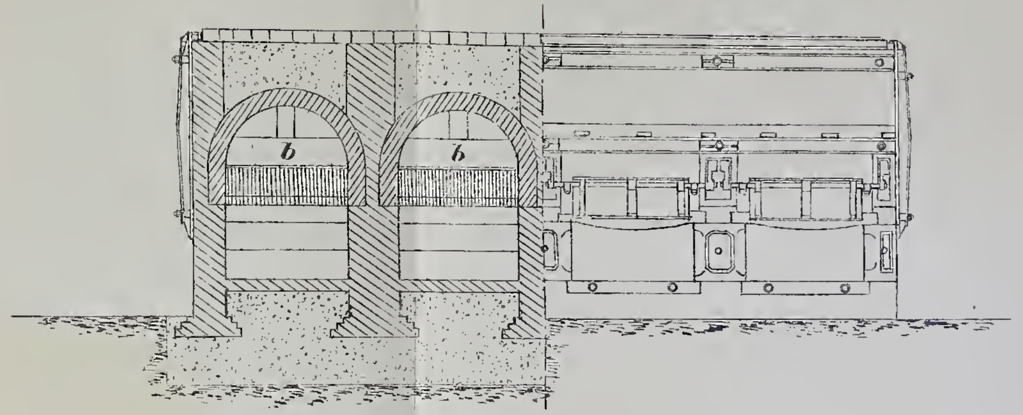
FRYERS DESTRUCTOR.

PLATE 4.

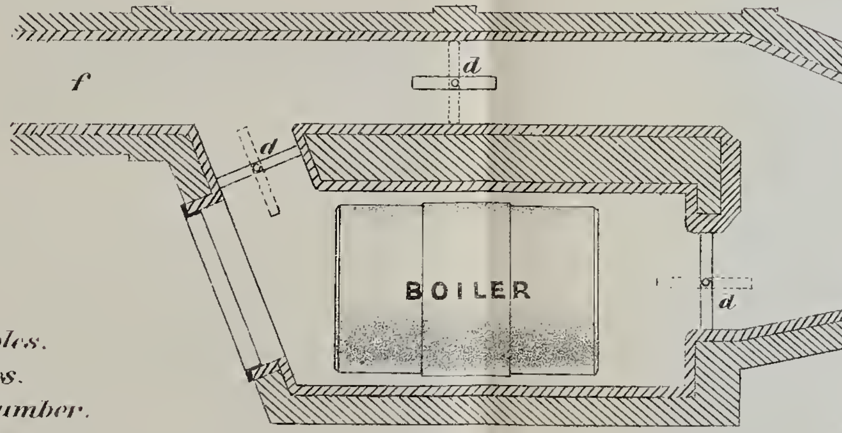
SECTION ON C.D.



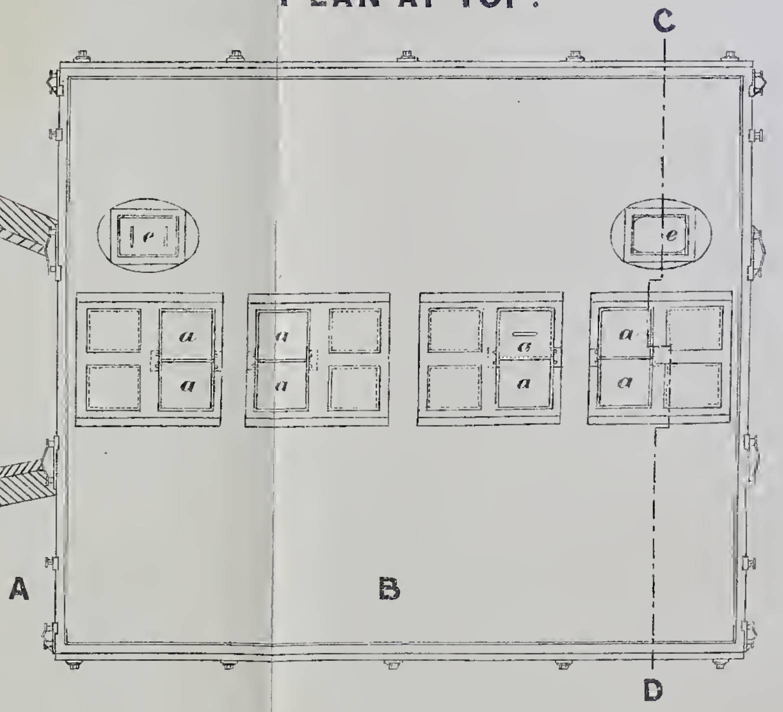
SECTION ON A.B. ELEVATION.



SECTIONAL PLAN OF FLUES.

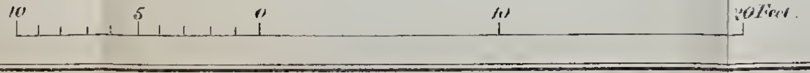


PLAN AT TOP.



a. a Feed Holes.
b. b Furnaces.
c Dust Chamber.
d. d. Dampers.
e. e Mattress Holes.
f. f. Flues.

Scale 8 Feet to an Inch.



DANGERFIELD, LITH 22, BEDFORD S^T COVENT GARDEN 8.87.14748.

inclination of 1 in 3 from back to front, and the bottom consists of a fire-brick hearth for the upper 4 ft. and a fire-grate for the lower 5 ft. On one side of the furnace the upper end of the hearth is prolonged with a steeper slope under an opening for the admission of the refuse from above, and on the other side is a passage whereby the products of combustion pass downwards to the main flue, a wall in the middle line of the furnace dividing the feed-hole from the flue opening. The main flue is under the hearth, and in the later destructors is made of large size to form a dust-chamber. The cells are preferably placed back to back with the feed-holes adjoining, there being only one opening above for the two cells. A somewhat larger opening, fitted with a cover, is provided over the middle of one or more of the furnaces through which infected bedding, condemned meat, &c. can be consigned to the hottest part of the fire. This opening might with advantage be made larger, as it is difficult to get in a mattress without cutting it up. There are cast-iron furnace mouths, with fire-doors at the front of the furnace. In the earlier destructors there were two mouths to each cell, but now one mouth, 5 ft. wide, with a door hinged at the top to open upwards, with balance weights, is preferred. The furnaces and flues are lined throughout with fire-brick, and corner pieces, stays, and tie-rods hold the brickwork together. A furnace or cell with the enclosing brickwork forms a rectangular mass about 12 ft. long, 7 ft. wide, and 12 ft. high, a group of four cells back to back measuring about 14 ft. by 24 ft., and a group of six cells about 21 ft. by 24 ft. A road is generally made by which the refuse is carted to a platform 2 ft. 6 in. or 3 ft. above the destructor, and another leading to the ashpit floor for the removal of the unburned portion of the refuse. In a few cases the refuse is raised to the top of the destructor by a lift or elevator, but a road for carts is far better.

The feed-openings at the top of the destructor are kept filled with refuse, which slides forward on the sloping hearth, and is partially dried by the heat given out by the burning material, and reflected from the reverberatory arch. It is helped forward by raking till it reaches the fire-grate, when everything combustible is burned to a hard clinker, which is withdrawn from time to time through the furnace doors.

The hot gases, or a portion of them, are usually passed through a multitubular boiler to make steam to supply an engine to work mortar mills and other machinery. The chimney shaft is usually at least 120 ft. high, and sometimes as much as 180 ft., to create a keen draught and carry off all offensive fumes, and the lower part is generally furnished with a fire-brick lining, with an air space for a height of 30 to 70 feet.

The clinker is removed about every two hours. It is lifted from the fire bars and raised above the burning cinders with suitable tools, and raked out of the furnace with any other thoroughly burned refuse. The fire is then spread evenly over the grate, and dry refuse is raked forward from the back sufficient to cover the fire evenly with a thickness of about four inches.

When the refuse is wet, a less thickness is enough. If too much refuse be drawn down at one time, the fire will become dead and black. At intervals of about twenty minutes, another thin layer of refuse may be raked forward and spread over the fire, but it is best to leave the fire undisturbed for half an hour before clinkering. The fire bars must always be kept covered, but the fire should not be too thick, 7 to 9 ins. is quite enough to ensure a clear bright fire. There should be enough refuse over the feed hopper to prevent air entering, but not so much as to prevent the proper charging of the cell, and there should be always sufficient refuse on the drying hearth ready to be raked forward for burning.

Leeds.

Destructors of this sort have been in continuous operation at Leeds since the beginning of 1878, when a six-cell destructor was completed at Burmantofts, 1½ mile from the centre of the town, to the north-east. In the following year another destructor of six cells was erected at Armley Road, about a mile to the west of the town hall. In 1882 four more cells were added to each destructor, and in 1887 two more cells were added at Armley Road. In both destructors the cells are arranged back to back over a main flue which, when the additional cells were added, was widened to 10 feet. The main flue branches into a bye-pass and a flue for heating a boiler, and the passage to one or the other is regulated by dampers. At Burmantofts the gases heat a multitubular boiler 10 ft. long and 6 ft. in diameter, which supplies steam to an engine having a 12-in. cylinder, and 2 ft. stroke, which drives two mortar mills, with pans 8 ft. in diameter, and 27 cwt rollers. These are on the ground floor. An incline of 1 in 14, laid with cast-iron tram-plates, leads to the upper floor, which is 15 ft. above lower floor, and 3 ft. above the the top of the destructor. The lower floor is open on two sides, but the upper floor is closed in and roofed over. The chimney is 150 ft. high and 5 ft. in internal diameter; it was built when the additional cells were added, the old colliery chimney used before being too small.

At Armley Road the chimney is 120 feet high and 6 feet internal diameter, and the building is of iron, 70 feet by 50 feet, supported on iron columns. A floor or platform of brick arching on plate-iron girders is reached by a road ascending 1 in 12, and another road leads downwards to the firing floor. The boiler is 9 ft. 2 ins. long and 8 feet in diameter, and the engine has a 14-inch cylinder and 30-inch stroke, and drives two mortar mills 9 feet in diameter.

The clinker from the furnaces is estimated at about one-fourth by weight of the refuse burned, but some tests by Mr. Newhouse, the superintendent of the Sanitary Department, showed the proportion of clinker and ashes to be one-third. Mortar is made of as much of it as there is a sale for, and the rest is used for ballast, street foundations, &c. The old iron and tin which is picked out and sold unburned fetches 1*l.* a ton on account of the solder, but the greater part goes through the destructors, and is sold for about 5*s.* a ton.

The total cost of the destructors, buildings, offices, machinery, &c., as stated in a report from the Chairman of the Sanitary Committee and the borough engineer, has been—

	£	*s.*	*d.*
Burmantofts destructor (10 cells) -	7,282	1	1
Armley Road destructor (10 cells) -	7,466	9	10

This includes the cost of a carbonizer no longer used, and other things not strictly appertaining to the destructors which it is impossible to separate.

The labour required at each destructor station is,

1 foreman, who acts as engine driver.
6 furnace-men, working three in day and three in night shifts.
1 labourer attending to mortar mills.

Considerable care is now taken with the charging and clinkering of the furnaces. At first all the cells were clinkered and charged one after the other every 2½ hours, as quickly as the men chose to do it, but now a pair of cells are charged every 25 minutes regularly. The result is that the temperature in the main flue is more uniform, and there is less smoke from the chimney.

The fires are kept continuously alight except when drawn for repairs; the furnaces are filled up and banked about 1 p.m. on Saturday, and the damper is closed at 7 p.m. till 12 on Sunday night. The amount burned in the year ending 31st August, 1886, in the 20 cells was 35,248 tons, giving an average of 34 tons per cell per week, consisting of refuse from ashpits with trade and market refuse. Mr. J. Newhouse furnished the following list of other things destroyed during the same period :—

Eleven cows, 3 calves, 17 sheep, 4 goats, 298 pigs, 5 turkeys, 2 carcases of beef, 28 quarters of beef, 9 cwt. of pork, 10 cwt. of pickled tongues, 12 cwt. of herrings, 218 cwt. of shell fish, 1 cwt. of sugar, 285 dogs, 109 cats, 13 foxes, 1 sea serpent, 147 mattresses, beds, pillows, and bolsters, 7 blankets, quilts, and sheets, 36 pieces of carpet, 7 hearth rugs and mats, 33 pieces of wearing apparel, 1 bedstead, 1 sofa, 1 chair, and 1 bundle of rags.

This is not an unusual year's work, and the destruction of diseased animals and condemned food is constantly effected without offence. On one occasion, on an outbreak of swine fever, 200 pigs were burned, and in one afternoon 50 were destroyed, three at once in a cell, only a faint odour of roast pork being perceptible on a hill to leeward of the chimney.

The working cost for the year ending 31st August, 1886, according to a statement furnished me by Mr. Newhouse, is as follows:—

——	Burmantofts.			Armley Road.			Total.		
	£	s.	d.	£	s.	d.	£	s.	d.
Wages - - -	572	1	2	590	7	0	1,162	8	2
Coal, oil, tallow, water, gas, &c. -	77	0	9	103	19	6	181	0	3
Implements and repairs -	67	8	4	159	19	7*	227	7	11
Rates, taxes, and insurance -	110	12	7	42	7	3	152	19	10
Lime (for mortar making) -	23	18	10	54	2	5	78	1	3
£	851	1	8	950	15	9	1,801	17	5
Less mortar and iron sold -	165	18	8	229	1	2	394	19	10
£	685	3	0	721	14	7	1,406	17	7

The capital cost has been, as already stated, 7,282*l.* 1*s.* 1*d.* at Burmantofts and 7,466*l.* 9*s.* 10*d.* at Armley Road. The loan is to be repaid by equal annual instalments of principal and interest in 60 years at 3½ per cent., which amount to—

	£	s.	d.
Burmantofts - -	291	17	9
Armley Road - -	299	6	4
Total - -	£ 591	4	1

for repayment of capital and interest.

The right to use the patent having been purchased for 2,000*l.*, 100*l.* a year for each destructor, appears to be a fair proportion to allow for royalty. The total annual cost of the destructors is therefore—

——	Burmantofts.			Armley Road.			Total.		
	£	s.	d.	£	s.	d.	£	s.	d.
Working cost - - -	685	3	0	721	14	7	1,406	17	7
Repayment of capital - -	291	17	9	299	6	4	591	4	1
Royalty - - - -	100	0	0	100	0	0	200	0	0
£	1,077	0	9	1,121	0	11	2,198	1	8

* Exclusive of new-fire bars (Galleys' patent).

The refuse destroyed in the year was:—	Tons.
At Burmantofts - - -	17,148
At Armley Road - - -	18,100
Total - -	35,248

which, at a total cost of 2,198*l.* 1*s.* 8*d.*, is at the rate of rather less than 1*s.* 3*d.* per ton delivered at the destructors, the cost per ton being very nearly the same at each station.

Experiments have been made at Armley Road with a view to increase the temperature by a freer admission of air through the fire-bars, and more effectually consume the gases evolved in burning. The result has been that all the furnaces at Armley Road were fitted with Galleys' Patent Venetian Furnace Bars in April 1886. These bars are fixed across the furnace, and can be opened or closed by a lever to regulate the passage of the air. By shaking the bars with the lever the clinker is loosened and slag is prevented from adhering and checking the draught.

Tests taken by Mr. Newhouse in March, April, May, and June, 1885, with a pyrometer gave temperatures in the furnaces with the ordinary bars, ranging from 750° to 1275° F., averaging 928° F.; and with Galleys' bars temperatures ranging from 742° to 1417°, averaging 1030° F., showing an average increase of temperature of 102° with the Galleys' bars. The residue of clinker and ashes after burning was found to be 7 cwt. 1 qr. 19 lbs. per ton with the ordinary bars, and 6 cwt. 0 qrs. 18 lbs. per ton with Galleys' bars, thus showing a more perfect combustion of the refuse with the latter. In the two cells added at Armley Road in 1887 Settle's rocking bars have been fixed.

At the Burmantofts destructor the ash places beneath the fire-grates have lately been closed, and air has been forced in by a blower, and by steam-jets. The former was found to require more power than was available, and the steam-jets are now under trial. A considerable current of air is induced by the jet, and the decomposed steam causes more rapid combustion, with considerably higher temperatures and more flame.

At Bradford a 12-cell Fryer's destructor has been in operation since 1880–1. There are two blocks, each of six cells back to back; the blocks measure 21 ft. by 24 ft., and are 24 feet apart, the chimney, 60 yards high, standing between them. Rocking bars have been fitted to two cells in place of the original fire-bars; they have answered very well in breaking up the clinker, and will be applied to all the cells as the old bars wear out. The heated gases from four cells are passed under and through a multitubular boiler, which provides steam at an average pressure of about 35 lbs. to the square inch for a 16 horse-power engine working three Bradford.

mortar mills. The building covering the destructor and machinery is 104 ft. by 64 ft., and has a floor 3 ft. above the top of the cells, leaving a pit 21 ft. by 24 ft. and 3 ft. deep over each block, into which the refuse is tipped from carts which come up an inclined road.

In the year ending October 1st, 1886, there were burned 20,380 tons of ashpit refuse and 1,696 tons of market garbage and trade refuse, together equal to an average of $35\frac{1}{3}$ tons per cell per week. Also the carcases of 12 beasts, 3 calves, 1 horse, 79 pigs, 505 dogs, 12 cats, 19 rabbits, $21\frac{1}{4}$ tons of fish, 2 cwt. of pickled tongues, 4 stones of butter, 1 stone of lard, 1 ton of cheese, 379 boxes of figs, 486 eggs, 84 baskets of fruit, 17 cwt. of apples, and a large quantity of infected bedding, &c.

The burning goes on continuously from Sunday night to Saturday afternoon. From trials extending over five weeks it was ascertained that the clinker and ashes remaining after burning amounted to about one-fourth in bulk and one-third in weight of the refuse burned. The clinker and ashes are ground up with lime, and excellent mortar is made, which is used for the Corporation works, and sold. About 75 tons per week are made on the average, and in the year ending October 1st, 1886, 3,927 tons were sold at the price of 8*s.* per ton for lias mortar and 6*s.* 6*d.* per ton for common lime mortar.

One of the mortar mills has been used in grinding market refuse and the shells of shell-fish into a pulp with about $\frac{1}{10}$th of lime. It is used for manure, but as yet no receipts have been derived from the sale of it.

The clean iron pots and pails are picked out of the refuse, and disposed of; all the rest goes into the furnaces, the best refuse being reserved for the cells that heat the boiler.

The cost of the works, as given by Mr. J. H. Cox, Assoc. M. Inst. C. E., the borough engineer, was as follows:—

	£	*s.*	*d.*
Ironwork and royalty - - -	1,888	0	0
Brickwork, 12 cells - - -	418	10	0
Chimney, 60 yards high - - -	650	0	0
Buildings, approaches, paving, &c. -	4,800	0	0
16 h.p. engine and shafting - -	246	0	0
Multitubular boiler - - -	360	0	0
Three mortar mills - - -	280	0	0
Land - - - - -	3,250	0	0
Total - -	£11,892	10	0

The working expenses for the year ending October 1st, 1866, as stated by Mr. Cox, were,—

	£	s.	d.	£	s.	d.
Wages, 12 men				805	13	8
General repairs				185	12	7
Lime (for mortar)				393	7	1
Coal, gas, water, oil, tallow, &c.				144	7	10
Books, stationery, and insurance				3	18	6
Rates, taxes, &c.				113	7	2
				1,646	6	10
Less received for mortar sold	1,204	18	10			
Contributions from markets for dealing with refuse	150	0	0			
Sundries	4	1	9			
				1,359	0	7
				287	6	3
To which must be added for repayment of 11,892*l.* in 50 years at 4 per cent. the annual charge of				553	11	11
				840	18	2

making the total cost of destroying 22,076 tons of refuse 840*l.* 18*s.* 2*d.*, or 9*d.* per ton. The cost of working is rather greater per ton than at Leeds, but the much greater receipt for mortar sold brings down the total cost per ton to a less rate. In the previous year the cost was 9¾*d.* per ton for 21,688 tons.

Bolton.

At Bolton a Fryer destructor of eight cells, back to back, is situated in a pit, the top of the destructor being 2 ft. 8 in. below the surface of the yard, so that the loaded waggons come in on the level and tip the refuse on to the top of the destructor. The clinker is raised from the firing floor by a steam lift, the travel of the steam piston being quadrupled by double sheaves and chains. A proportion of the heated gases, which can be regulated by dampers, is passed through and under a multitubular boiler 10 ft. long and 7 ft. 6 ins. in diameter. A Lancashire boiler, 30 ft. long and 7 ft. in diameter, is heated by selected ashpit refuse, from which the dust and small ashes have been separated by passing it over a screen. The two boilers are coupled together and afford steam at 65 lbs. pressure for the lift, a steam-pump, and two engines of 18 and 27 horse-power, which drive four mortar mills with pans 9 feet in diameter, and two mills for grinding together pail contents, offal, and street sweepings into a manure which is sent away by rail. The chimney is 180 feet high, with an internal area of 49 square feet at the base. The destructor, manure works, &c. are covered in by a substantial building.

In the daytime, when it is necessary to keep up plenty of steam, the furnaces are stirred and the clinker is broken up every ten minutes. At night, when steam is not wanted, they are clinkered every two hours. The fires are made up at mid-day on Saturday, and are left in charge of one of the men to keep them alight till midnight on Sunday. The main flue requires to be cleaned out every six weeks on the average.

There are seven men employed in connection with the destructor, viz, four by day and three by night, and one man by day to fire the Lancashire boiler, besides an engine tenter.

The cost of the works connected with the destructor is stated by Mr. Brockbank, the borough surveyor, to be as follows:—

	£	*s.*	*d.*
Destructor, chimney shaft, boilers, &c. -	4,300	0	0
Mortar mills, hoist, shoot, &c. - -	1,700	0	0
Proportion of cost of driving power -	200	0	0
Proportion of cost of site, buildings, paving, &c. - - - -	3,000	0	0
	£9,200	0	0

The total amount collected by the Scavenging Department in the year ending December 31st, 1886, was as follows:—

	Tons.
Ashpit and privy refuse - - - -	36,365
Pail contents - - - -	10,599
Street sweepings - - - - -	9,114
Butchers' offal - - -	1,062
Market garbage and shop sweepings - -	865
	58,005

Of this, 18,360 tons was sold as manure, 13,513 tons was taken to tips, and 15,191 tons was burned in the destructor and the Lancashire boiler, the former consuming 13,375 tons, being at the rate of $32\frac{1}{7}$ tons per cell per week.

Careful trials made in 1883 proved that the refuse was reduced to one-third in weight and bulk by burning, and of the residue that two-thirds is clinker fit for mortar making, one-sixth is useful at the sewage outfall works, and one-sixth consists of old tins and iron, brickbats, &c. The amount of clinker fit for mortar making would thus have been 3,376 tons in 1886, enough to have made 10,100 tons of mortar. The sales actually amounted to 6,745 tons in the year.

The cost of working, from information given by Mr. John Stewart, the superintendent, was in 1886—

	£	s.	d.	£	s.	d.
Destructor:—						
Wages		—		536	4	9
Repairs, gas, and sundries		—		62	9	0
Rates and taxes		—		22	4	7
				620	18	4
Mortar mills:—						
Wages	195	12	3			
Lime and water	593	7	4			
Repairs, gas, and sundries	109	12	1			
Rates and taxes	22	4	7			
				920	16	3
Repayment of principal and interest, 9,200*l.* in 60 years at 3½ per cent.		—		368	16	3
				1,910	10	10
Deduct receipts from sale of mortar, 5,893 tons 12 cwts. 2 qrs. of common mortar at 5*s.*	1,473	8	1			
851 tons 7 cwts. 2 qrs. of hydraulic mortar at 6*s.* 8*d.*	283	15	10			
				1,757	3	11
				153	6	11

being for the 15,191 tons of refuse burned less than 2½*d.* per ton. This cost, small as it is, at which this portion of the refuse of the town has been disposed of, would have been altogether extinguished had the whole of the clinker been made into mortar and sold.

Bury. At Bury a destructor of four cells, back to back, was erected on part of the town yard in 1881. The cost, including a multitubular boiler, 7 ft. 6 ins. diameter and 10 ft. long, engine of 8 horse-power, mortar mill and building, but exclusive of land, was 3,500*l.*; the chimney, which is 180 ft. high and 6 ft. in diameter, and the main flue, being large enough for eight cells. The high-level road leads to a platform at one face of the destructor, and 2 ft. 6 ins. above the level of the top of it. The fires are banked at noon on Saturdays and left altogether without attention till 12 o'clock on Sunday night, from which time they burn continuously till Saturday.

During the year ending 31st of March 1886, 6,326 tons were burned in the destructor, including 255 tons of butchers' and greengrocers' offal and refuse. Of the remaining 6,071 tons about a third is estimated to be dry refuse from ash-tubs, and the rest the contents of the combined privies and ash-pits, of which about one-fourth is considered to be excreta. The quantity burned thus amounted to 30½ tons per cell per week of 132 hours. From a trial made it appears that the refuse is reduced to about half its weight, and rather more than one-third of its bulk of clinker, ashes, and dust. 1,582 tons of mortar were made in the year, valued at 423*l.* 11*s.* 2*d.*, 395 tons of it was used for Corporation works, and the rest sold to the public at about 5*s.* 6*d.* per ton. Very little is picked out of the refuse before it is burned. The flue is cleaned out every two months, when about 20 cartloads of dust are taken out. Very little smoke was visible at the time of my visit, and no dust has ever been detected from the chimney. There have been, however, some complaints of smell attributed to the chimney.

The renewals found necessary have been exceptionally great. The fire-brick lining to the furnaces had been renewed twice, and the third set of rollers to the mortar mill were being put in at the end of 5½ years from the completion of the works. The false bottom to the mortar pan was said to wear out in four months.

The cost of working during the year ended March 31st, 1886, as furnished me by Mr. Wilkinson was,—

	£	*s.*	*d.*	£	*s.*	*d.*
Destructor:—						
Wages, 4 men at 26*s.* a week	275	12	0			
Carting away ashes, dust, &c.	52	10	10			
Repairs (new fire bars, &c.)	42	4	5			
Gas, coke, and sundries	60	8	2			
Rates, taxes, gas, and water	13	8	6			
				444	3	11
Mortar Mill:—						
Wages	112	19	6			
Lime	120	8	9			
Repairs (new rollers, &c.)	85	5	6			
Water, insurance, &c.	18	16	5			
				337	10	2
				781	13	1
Less received for mortar sold	—			423	11	2
				358	1	11
Add:—						
Repayment of cost 3,500*l.* in 30 years	201	5	0			
Rent of site	30	0	0			
				231	0	0
				589	0	0

This amounts to 1*s.* 10¼*d.* per ton as the total cost of destroying the 6,326 tons of refuse burned during the year.

Preston.

At Preston a destructor was erected in 1886 consisting of eight cells side by side, with a dust chamber 8 ft. 10 ins. wide and 6 ft. 3 ins. high, having four cross walls to catch the dust. The high-level road leads to a tipping platform at the back of the cells, and the destructor and platform is covered by a building 58 ft. by 38 ft. supported in front on iron columns. The chimney is 180 ft. high and 7 ft. square inside at the base, and there is an inside lining of fire-brick, with an air space for a height of 67 ft. There is a multitubular boiler, but no mortar mill as yet.

The cost of the destructor, exclusive of land, is stated by Mr. Hudson Reah, Assoc. M. Inst. C. E., the borough engineer to be,—

	£
Ironwork to cells, &c., and royalty -	1,398
Multitubular boiler - - -	310
Brickwork in setting cells and boiler -	746
Chimney - - - -	680
Buildings, approach road, &c. - -	987
	£4,121

The burning has gone on day and night continuously since the 8th of September, 1886, and up to the end of May had worked 226 days, exclusive of 40 days stoppages for repairs, cleaning flues, and holidays. In that time about 7,300 tons of ash-pit refuse were burned, besides a quantity of bad meat, fish, and market-refuse. The residue of clinker is about one-third of the refuse burned.

There are two shifts of men employed, with 3 men in each, costing in wages £8. 11*s.* 6*d.* per week. The practice is to loosen the clinker about every 10 minutes, and clear it out of the furnace once in six hours. The main flue requires clearing out every two months, the ashes in that time reaching the top of the cross walls in the flue. There was only a slight smoke visible from the chimney at the time of my visit.

Salford.

At Salford a six-cell destructor has been in use since 1882 to burn the dry refuse, and the cleanest part of the privy-and-ashpit refuse not mixed with night-soil to make manure. The cells are side by side, and a retaining wall at the back of them supports a platform 3 ft. above the top of the destructor and 20 ft. wide which is reached by a continuation of the high-level road to the manure tips. The platform and destructor are covered in by a brick building, one wall of which stands on the face wall of the destructor, and a lower shed covers the firing floor. The dust chamber is 8 ft. wide and has cross walls, to catch the dust, fitted with moveable iron plates in the middle part, which are removed when the flue is cleared out. The chimney is 60 yards high and 5 ft. 6 ins. diameter. There is no mortar mill or boiler and the clinker is given away, or carted to tips.

The superintendent, Mr. G. E. Hall, informs me that the cost was as follows:—

	£
Ironwork and patent rights - -	995
Building, and setting ironwork -	265
Retaining wall - - -	110
Shed - - - - -	359
Chimney - - - -	558
Laying on gas, water, &c. - -	113
	£2,400

The site was the property of the Corporation.

In the winter months the destructor is worked day and night from early on Monday morning till Saturday afternoon. In summer, when nearly all the ash-pit refuse is wanted to mix with night-soil, the fires are banked up from 5 or 5.30 p.m. till 6 a.m.

Three men are employed to feed and attend to the destructor, and the working cost is stated by Mr. Hall to be—

	£	
Wages - - - -	150	per annum.
Repairs - - - -	5	,,
Disposal of clinker - -	150	,,
Interest and repayment of loan -	100	,,
	£405	,,

In the year ending August 31st, 1886, 5,314 tons of refuse and about 6½ tons of unsound meat, fish, and eggs were burned, being an average of only 17 tons per cell per week. Under these circumstances the total cost of burning the refuse, including interest and repayment of capital, appears to have been about 1*s.* 6*d.* per ton.

Newcastle.

At Newcastle-on-Tyne the nature of the site, a slope bordering on an old quarry, has led to an arrangement of six cells side by side in line with another group of six cells on the other side of the chimney. As yet the foundations only of the second six cells are built. There is a dust chamber 8 ft. 9 ins. wide, with three cross walls to catch the dust in its length of 42 feet beneath the drying hearths of the furnaces. The walls are built dry, and are pulled down when the flue has to be cleared every month. The chimney is 150 feet high, 6 feet in diameter at the base, and 6 feet 9 inches at the top, and has an inner lining of fire-brick, with an air space for 54 feet of its height. The destructor has a shed on the top and a lean-to shed over the furnace mouths. A tramway is extended from the town to the upper level, 3 feet above the top of the destructor, and it is intended to collect the refuse in special tramway waggons at covered depôts, and take it at night to the destructor.

The cost of the works up to the present has been, according to Mr. W. G. Laws, M. Inst. C. E., the borough engineer—

	£	s.	d.
Chimney and flues for 12 cells - -	523	5	2
Six cells, including ironwork - -	1,780	17	7
Sheds and fittings for six cells - -	435	16	1
Roads, tramway, fencing, boundary walls, &c. for 12 cells - - - -	2,275	14	3
	£5,015	13	1

Of this, 1,400*l.* is considered to be expenditure connected with future extension.

During the year ending June 29, 1887, 10,036 tons of refuse, consisting of shop refuse with about 20 per cent. of ashes, the sweepings from paved roads, and about 10 per cent. of privy and ash-pit refuse were burned, equal to 32¼ tons per cell per week. Two men are employed about the destructor by day and two by night, and an extra man occasionally.

The cost of working for the year was :—

	£	s.	d.
Labour - - - -	298	1	7
Material - - - -	32	4	11
	330	6	6
Less receipts from sale of ashes and cinders, and tickets for burning refuse	45	13	9
	284	12	9
To which add for interest and repayment of 5,015*l.* 13*s.* 1*d.* in 25 years -	304	6	0
	£588	18	9

which gives, for the total cost of burning 10,036 tons, the rate of rather more than 1*s.* 2*d.* per ton. If the 1,400*l.* of capital spent with a view to future extension be not included, the rate will be rather more than 1*s.* per ton.

Hull.

At Hull six cells of a Fryer destructor are arranged back to back, forming a block 22 ft. by 24 ft. in one corner of a building 43 ft. by 45 ft. square. There is a dust chamber in the middle of the block 10 ft. 4 ins. wide, and 6 feet 6 ins. high. The chimney is 180 feet high. The furnaces have wide mouths, the frames of which have buckled and cracked with the heat. The platform for tipping the refuse is on a level with the top of the destructor, and, in consequence, both the arches of the furnaces and the iron frames to the feed openings appear to have been damaged by the carts going on them. The refuse burned consists principally of sweepings from shops, paper, market sweepings, and vegetable refuse, with ashes from bins, and a large proportion of glass and old tins. Nearly all the ashes of the town are mixed with the privy contents for manure, and the refuse burned is generally of a light dry nature, so that it is not considered safe to heap it over the feed-holes. Two men are employed, and sometimes in summer, when there is much less to burn, only one. At 6 a.m. they begin to clinker the furnaces which have been banked up since the previous evening. Clinkering and filling in refuse takes them till mid-day. After dinner they thoroughly clinker again and fill up ready for banking up the fires at 5.30. The flues are cleared every month after letting the fires down for a day.

The cost of the destructor and raised road and the land occupied by them was 4,345*l.*, for which money was borrowed, repayable in 60 years. There are as yet no boiler or machinery in connection with the destructor, but room is provided for them.

In the year 1866 about 6,000 tons of refuse were burned, being about 19 tons per cell per week on the average.

The cost of working during 1886, as furnished by Mr. Wells the superintendent, is—

	£	*s.*	*d.*
Wages of two men - - -	130	0	0
Repairs - - - - -	40	0	0
Gas, water rates, &c. - - -	11	18	0
	181	18	0
Deduct value of old iron, tin, clinker, &c. -	10	0	0
	171	18	0
Add interest and repayment of loan, 4,345*l.*, in 60 years - - - -	173	16	0
	£345	14	0

being nearly 1*s.* 2*d.* per ton of material burned.

Derby.

At Derby a six-cell destructor, erected in 1881, consumes all the ash-bin refuse of a population of 92,000, except the fine ashes which are used for mixing with the pail contents. The cells are arranged back to back over a flue 4 feet wide and 6 feet high, through which the heated gases pass to a multitubular boiler. The chimney is 160 feet high and 6 feet in diameter. The refuse is carted by an inclined road to the upper floor of a substantial brick building, 90 feet by 67 feet, 3 feet above the top of the destructor, which thus forms the bottom of a pit in the floor, 24 feet by 21 feet, and 3 feet deep. The refuse is shovelled through a grid in the floor on to an inclined screen, by which the fine ashes are separated from the rougher refuse. The latter falls into a pit, from which it is lifted by a chain and bucket elevator, and delivered at the top of the destructor.

About 11,900 tons of refuse were carted to the upper floor of the building in 1886, from which about one-third was screened out, leaving 7,900 tons which were burned in the destructor, besides which about 3,000 tons of tins, brick ends, and rubbish of all sorts from middens and vaults, and screened out of the pails as they were emptied, were carted direct to the destructor, making a total of about 10,900 tons which was passed through the destructor in the year, or an average of 35 tons per cell per week The fires are banked up at 2 p.m. on Saturday, and are started again at 12 on Sunday night, with the help of old baskets, &c., thus burning night and day for 134 hours per week. Two men are employed on the firing floor, one of whom attends to the clinkering of the six furnaces, while the other clears and wheels away the clinker. This arrangement is to ensure regularity in clinkering. By night one man attends to both. There are besides, two men on the top of the destructor by day and one by night, and a man at the top of the screen and a man and a boy at the bottom by day.

Nottingham.

A Fryer destructor of four cells is in use at Nottingham, and also a modified destructor furnace, with a boiler over it, like those at Warrington, to be presently described. The four cells are side by side, and the flue, which is 5 ft. 8 in. wide and 7 ft. 6 in. high, leads direct to the chimney, the heat from the cells not being utilized. There is no high-level road, but the ordinary refuse is lifted from the ground by an elevator, consisting of buckets on an endless chain, to a revolving screen, from which the fine ashes are discharged into carts, to be taken for mixing with excreta from the pails, and the residue is delivered to the feed-holes of the boiler furnace and to the top of the destructor. A steam-hoist raises the refuse not worth screening direct to the top of the destructor. The whole of the works are covered by a substantial building. The chimney is 160 feet high, a grid near the base catches paper, &c., and there is no complaint of dust escaping. The destructor has needed no repairs since it was put up in 1882.

The steam from the boiler supplies an engine of about 35 indicated horse-power, driving a dynamo, supplying 10 electric lights of 1,000 candles, which light the works at night while the pails are being delivered. By day the engine works a mortar mill used for grinding oyster shells, shell-fish, and vegetable refuse for manure, and the screen and elevator. The boiler also supplies steam for a donkey-engine and the steam-hoist.

The cost, according to a statement furnished to me by Mr. Arthur Brown, M. Inst. C. E., the borough engineer, was :—

	£	*s.*	*d.*
Engines, boiler, ironwork to cells, elevator, &c. - - - -	1,956	4	8
Brickwork to cells and boiler - -	748	5	11
Chimney and foundation - -	1,401	8	0
Buildings, paving, &c., &c. - -	2,255	3	3
	£6,361	1	10

There are seven men employed about the destructors and boiler, besides an engine-driver and a foreman. One man attends to the four cells of the destructor, one to the boiler-furnace, one to the elevator and two to the steam hoist, one to the mortar mill, and one to carting the ashes from the screen to the boats and trucks. For the year ending 25th March 1887 the working expenses were 591*l.* 6*s.* 10*d.*

The quantity of refuse burned in a year is not known, but in a week during which the refuse tipped into one cell was weighed, 24¼ tons of the worst sort was burned, leaving a residue of 5½ tons of clinker and 2 tons of fine ashes, together 31 per cent. of the refuse burned.

Blackburn. At Blackburn there is a destructor of four cells arranged back to back. It forms part of the night-soil and scavenging depôt at Audley, and Mr. McCallum, Assoc. M. Inst. C.E., the borough engineer, states, that the proportion of the cost of the site occupied by the destructor was 2,064*l.*, and the cost of destructor, cells, chimney, approach road, wall, &c. was 2,106*l.* The chimney is 105 feet high. The burning goes on from 6 o'clock on Monday morning till noon on Saturday, when the fires are banked, and occasionally looked to on Sunday. Two men are employed, one by day and one by night, at an average cost of 2*l.* 19*s.* per week.

Until lately no record has been kept of the quantity of refuse burned, but two or three weekely averages give a result of 27 tons per cell per week, the material being ordinary ash-pit refuse.

To remedy complaints of the escape of unconsumed paper, straw, &c., and fine dust from the chimney, a fume cremator was added, but with the result of lessening the quantity burned by one-third, and considerably increasing the cost. The nuisance complained of was, however, abated. The fume cremator will be adverted to further on.

Heckmondwike. At Heckmondwike a Fryer destructor of two cells was erected in 1879, and a third cell was added in 1883. The three cells are alongside each other, and form a block 21 feet by 14 feet standing in the middle of a building 16 yards square. A boiler 10 feet long and 6 feet diameter is heated by the gases on their way from the furnaces to the chimney, and makes steam for a 12 horse-power engine which drives a mortar mill and a cylindrical screen situated on the ground floor at the back of the destructor. A raised road leads by a timber gangway to a platform which is level with the top of the destructor and extends from the face of the cells to the back of the building. On the platform the refuse is tipped, and clean pots and old iron and tin are picked out. The chimney is 40 yards high, no smoke was visible at the time of my visit, and no dust has ever been found to come from the chimney. Some complaints of smell have been made, but none have been substantiated as arising from the destructor.

The cost of the destructor, including chimney, building, high-level road, engine, boiler, mortar mill, and sifting machine was 1,512*l.* The site was the property of the local board, occupying one half of the town yard purchased for 600*l.* The total cost of the three cell destructor may, therefore, be put at 1,812*l.*, or 604*l.* per cell.

The refuse burned consists of everything removed from the ash-pits and middens, except the night-soil which is tipped into the farmers' fields free of charge.

About 1,400 tons per year are burned, equal to 9 tons per cell per week, but the destructor only works 9 hours per day and up to noon on Saturday, on the evening of which day more refuse is heaped on and the fires are banked up till Monday morning. The clinker amounts to about one-third by weight of the refuse burned; it is ground with lime and made into mortar, which sells for 5*s.* a ton when not used by the surveyor. It is also ground separately and screened to three qualities, finding a ready sale at 2*s.* a ton for asphalt floors, mortar, concrete, and plaster.

The cost of working for the year ending 25th March 1886, as furnished by Mr. Gledhill, the surveyor, is as follows: —

	£	*s.*	*d.*
Wages (1½ man) - - -	93	12	0
Repairs, gas, oil, insurance, &c. - -	16	0	0
Lime - - - -	14	8	0
	124	0	0
Repayment of loan, 1,550*l.* in 20 years -	120	8	5
	244	8	5
Deduct for sale of lime, clinker, old iron, &c. - - - -	83	1	6
	£161	6	11

amounting to more than 2*s.* 3½*d.* per ton of refuse burned.

Warrington.

In the furnaces at Warrington, three in number, a multitubular boiler is placed over the sloping fire-grate and drying hearth of a Fryer furnace. The fire-grate is 6 ft. long and 7 ft. 6 ins. wide, and the hearth 9 ft. long with a slope of 1 in 3. The boiler, 11 ft. long and 6 ft. 6 ins. in diameter, is 5 ft. above the lower end of the fire-grate, and 1 ft. 6 ins. above the upper end of the hearth. The refuse is fed into two hoppers, one on each side, opening to the platform above and on to the middle of the drying hearth, from whence it is raked forward to the fire-grate. The draught passes under, through, and back by the sides of the multitubular boiler, and downwards to the main flue at the back. The chimney shaft is 120 ft. high and 3 ft. 6 ins. in diameter.

The refuse burned is the contents of the ash-tubs, from which it is found necessary to screen out the fine ashes as they clog on the fire-bars. The burning goes on day and night for 125 hours per week, in which time 180 tons of refuse are consumed, or 60 tons per furnace per week. The clinker amounts to 50 to 60 tons per week, or nearly one-third of the refuse burned. It is used for concrete and street foundations.

The steam is used for evaporating excreta in vacuum pans and Firman's dryers, for which a pressure of 60 lbs. has to be maintained, and the boiler and furnaces are parts of the works at Longford, where the pail contents are manufactured into manure.

The cost of the three boilers and furnaces, including erection, was 1,700*l.*, and of the chimney 265*l.* The working expenses for two men screening and feeding the refuse by day and one by night, and two men by day and two men by night attending to the fires and clinkering, amount to 7*l.* 10*s.* per week, equal to 10*d.* per ton of refuse burned, in return for which all the steam for manufacturing the manure is obtained, besides the clinker.

In the foregoing towns the privy-and-ashpit or the pail-closet systems, are the prevailing methods of excreta removal. In the following instances, destructors deal with the refuse of towns, depending entirely on the water-carriage system.

City of London.

The City of London has a destructor of 10 cells at Lett's Wharf, which burns the paper and dry rubbish collected from shops and warehouses, and the refuse material left after the ashes, cinders, and anything else worth picking out have been sorted by women from the contents of the dust carts.

The bodies of the carts containing shop refuse are lifted by steam, and tipped on the top of the destructor. The carts containing ashpit contents are tipped in sheds and sorted, and the rubbish to be burned is carried by men to the top of the destructor in baskets. The cells are arranged back to back over a dust chamber 10 ft. 4 ins. wide and 6 ft. high, the flue from which leads to a 30 horse-power boiler, and to a chimney shaft 150 feet high. In communication with the latter there is also an open furnace about 9 feet square and 10 feet high, with fire-bars 2 ft. from the ground, intended for baskets, matting, shavings, and other bulky material, but in which other refuse appears to be burned.

There are three mortar mills, but it was found that the clinker would not make saleable mortar, and they are only used for grinding oyster shells. The residue, after burning, amounts to about 10 per cent. of the refuse burned. It contains a large proportion of small ashes, due, no doubt, to the quality of the refuse; it is valueless, and is barged away.

The destructor is set to work at midnight on Sunday, and burns continuously till 8.30 on Saturday evening. Colonel Haywood, M. Inst. C. E., the city engineer, states* that in the year 1886 it was in constant operation, except for 13¾ days for repairs, and dealt with 15,580 tons of refuse out of 35,820 tons collected, equal to 31 tons per cell per week of 135½ hours. The men are employed in three shifts of eight hours, and there are generally three on the top feeding the furnaces, and three below firing and removing the clinker and ashes. There have been complaints of smell, and also of the escape of dust and partially burned and burning paper from the chimney. The latter has been stopped by a grid in the flue.

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* Report to the Commissioners of Sewers for 1886.

Whitechapel.

The only other destructor yet erected in the Metropolis is in Whitechapel. It is in a densely populated neighbourhood, and the brickwork of the cells is within a foot of the walls of adjacent dwelling-houses. There are eight cells arranged back to back over a dust chamber 10 ft. 6 ins. wide and 6 ft. high to the crown of the arch. The tipping platform for the carts is over one firing floor, and it and the destructor are covered by a building 40 ft. by 28 ft. on iron columns with corrugated iron sides. A lean-to iron roof covers the other firing place. The upper part of the inclined road and the platform is on iron columns and girders, with brick arching. The chimney, which is reached by an underground flue 60 ft. long, 7 ft. high, and 4 ft. wide, is 180 ft. high and 6 ft. in diameter at the top. There is no boiler.

The cost of the works, as furnished by Mr. W. La Riviere, surveyor to the Whitechapel Board of Works, was as follows:—

	£
Land, 8,000 square feet	4,000
Ironwork, royalty, &c.	2,347
Brickwork in cells, flues, &c.	2,466
Road, paving, &c.	
Chimney and foundation	2,500
Boundary walls, &c.	850
Cottage for foreman	508
	£12,671

Two furnace-men, three labourers, and a boy are employed by day, and two furnace-men and two labourers by night. The fires are banked from midnight on Saturday till midnight on Sunday. The results of continuous working have not yet been ascertained, but in 24 working days from April 14 to May 12, 1,030 loads were burned, equal to 32¼ loads per cell per week. The previous month, allowing for holidays, gave the same result. A load is said to be more than a ton, but the weight is not known. The clinker and ashes produced are about 23 per cent. of the refuse burned, 18 per cent. being clinker, and 5 per cent. ashes and dust. From 12 to 15 tons of fine dust is cleared out of the flue every month. No return is derived from anything, and the removal of dust and ashes has to be paid for.

Ealing.

At Ealing a destructor has been for several years past successfully applied to burn the sludge from the sewage works, as well as the dust-bin refuse of the district. There are four cells side by side, on the top of which a part of the refuse is tipped direct from a high-level road. The sludge is mixed with ashes, &c. from the dust-bins, after the rougher materials, pots, tins, &c. have been picked out, in stanks formed by planks set on edge and supported by brick piers. A bed of ashes is formed, on to which the sludge is run, being forced by air pressure from the sludge well. Alternate layers of about 4 ins. of ashes and about 12 ins. of sludge, with a little lime spread over it, are added to a depth of about 4 feet. In about 12 days the mass is dry enough to be dug out, and conveyed to the destructor in small trucks which run on moveable railways, and are raised by a hydraulic lift.

During the year ending March 25, 1887, 3,267 tons of house refuse were received at the works, of which about two-thirds went direct to the destructor, and the other one-third was mixed with sludge in the manner just described, producing 7,688 tons when ready for burning. Of this mixture, 1,565 tons was carted away by market gardeners for manure, and the rest, amounting to 3,945 tons, was burned, together with the 2,178 tons of ashes taken straight to the destructor. The total of 6,123 tons burned gives an average of 29½ tons per cell per week. The fires are banked up for about six weeks in the year, but otherwise they burn continuously. The mixture of ashes and sludge is said to burn better than house refuse alone, though as taken from the stanks it is stated to contain 67 per cent. of water.

The burning of sludge with ashes was from the first successful, but dust and offensive vapours escaped from the chimney, and at times became a nuisance. To prevent this, Mr. C. Jones, Assoc. M. Inst. C. E., devised an additional furnace, called a fume cremator. In this, the gases from the destructor on their way to the steam boiler are made to pass over a coke fire on a grate about 6 ft. 6 ins. long by 4 ft. wide in a furnace covered in by a fire-brick arch rising 3 ft. above the fire-bars. The coke is fed in by openings at the top, and the fire is stoked through doors at one end. The ash-pit is closed and air is supplied to the fire through air-flues at the sides. When the fires are fairly alight the air-flues are partially closed by dampers. The fuel used is coke breeze, of which about one chaldron per day, costing 1*s.* 6*d.*, is burned. The cremator is managed by the destructor firemen, and thus there is no extra expense for labour.

The cost of the four-cell destructor, a chimney 140 ft. high, and the cremator furnace is stated by Mr. Jones to have been 2,000*l.*, exclusive of the site, which was already the property of the local board. The labour employed comprises two men by day and one by night, with assistance from the engine-driver for stoking and feeding, two men screening ashes, and two men moving the sludge mixture, and costs 380*l.* per year.

The heat from the destructor and cremator is utilized by a boiler, which supplies steam for an engine which drives the lime-mixing machines and clay mixer of the sewage works, works the lift pump, chain pump, mortar mill, and the atmospheric ram for raising the sludge. The clinker is used for road foundations and for making mortar and artificial stone slabs for paving. Some return is derived from the old tin and iron and "hard core" picked out of the refuse.

The following figures are given by Mr. C. Jones :—

	£	*s.*	*d.*	£	*s.*	*d.*
Cost of labour - -	380	0	0			
Cost of coke breeze - -	36	8	0			
Charge for repayment of loan (2,000*l.*) - -	115	13	4			
				532	1	4
Less value of steam-power -	171	12	0			
„ „ clinker, 1,960 tons at 1*s.* -	98	0	0			
„ „ rags, bottles, &c.	32	5	6			
				301	17	6
Total annual cost -	—			230	3	10

being rather more than 9*d.* per ton for the 6,123 tons of sludge and house-refuse burned. The cost of the site is, however, left out of account, with other minor expenses.

Southampton.

At Southampton the dust-bin refuse is burned in a Fryer destructor, and generates steam for the air-compressing machinery in connexion with Shone's ejectors, which are used for lifting the sewage effluent and sludge from the precipitating tanks, and also sewage and storm water from low-lying sewers in time of rain. There are six cells arranged back to back over a dust chamber 10 ft. wide and 7 ft. high, and between this and the chimney which is 160 ft. high and 7 ft. in diameter, is a 30 horse-power multitubular boiler 11 ft. long and 6 ft. 6 ins. in diameter, and in a bye-pass is a smaller boiler of 12 horse-power to keep up the steam, while the larger boiler and flue are being cleaned or repaired. The air-compressing engines keep up a pressure of 70 to 80 lbs. on the square inch in the reservoir by day when the ejectors are discharging every three hours. By night and on Sundays the pressure is allowed to fall to 30 lbs. on the square inch, as it can soon be increased if any demand on the pumping power of the ejectors arises. The ordinary work performed is the lifting of about 500,000 gallons of sewage effluent about 10 ft. and about eight tons of sludge 24 ft., through a mile of 4-inch pipe every 24 hours.

The destructor station is a mile from the precipitating tanks, and the compressed air is conducted in a 5-inch main to two ejectors, one of which receives the top water from the precipitating tanks through a floating arm, and discharges it into Southampton Water; and the other one, which comes into work automatically when the first one has discharged the clear effluent, and forces the sludge through a 4-inch main back to the destructor station. It is there mixed with ashes and sold for manure at present, but it is intended, if the demand for the manure fails, to burn the sludge in the destructor; and for this purpose a tank 2 ft. 6 ins. wide and 1 ft. 6 ins. deep is provided under the tipping platform into which the sludge can be delivered and run into the refuse before it is fed into the furnaces. Hitherto, the sludge has been burned only by way of trial. Twenty or thirty tons of sludge were burned at the rate of six tons in 24 hours in three cells without difficulty, and no perceptible increase of smoke was observed from the chimney.

The burning of refuse began in the summer of 1886, and all six cells were in use until the winter, when the farmers began to take a part of the refuse for manure, and four cells consumed the rest. The material is the ash-bin refuse from a wholly waterclosetted town, and it amounts to 215 tons per 1,000 population per year.

In the year ending August 3rd, 1887, 9,400 tons were burned, being about 30¾ tons per cell per week for the six cells on the average, but in some weeks as much as 56 tons per cell were burned.

The proportion of clinker and ashes to the refuse burned is about one-fifth; there being rather more ashes than clinker. One man by day and one by night attend to the clinkering, and one man by day and one by night to the feeding of the furnaces. The ashes are used for mortar and for tar paving for paths, and the yard has been raised with the clinker. The principal return derived from the burned refuse is in the power obtained for the air-compressing engines, which indicate 31½ horse-power. Mr. W. B. G. Bennett, M. Inst. C.E., the borough engineer, by whom the works have been designed, considers that 21 tons of ash-bin contents afford, when burned, about 25 horse-power.

The cost of the works as furnished me by Mr. W. B. G. Bennett, was,—

	£	*s.*	*d.*
Ironwork of six cells, boiler, &c. - -	1,370	0	0
Brickwork in cells, boiler setting, and building - - - -	677	0	0
Chimney shaft - - - -	1,253	0	0
	£3,300	0	0

The working cost for the year ending August 3rd, 1887, was,—

	£	*s.*	*d.*
Labour, two men by day - -	109	0	0
,, ,, ,, night - - -	124	0	0
	233	0	0
Repayment of loan and interest - -	154	10	6
	387	10	6
Deduct value of clinker and ashes - -	120	0	0
	£267	10	6

This is less than 7*d.* per ton for the 9,400 tons burned; but it is to be noted that site, approaches, &c. are not included in the cost of the works, and the working cost includes nothing but labour.

Buxton.

A destructor has been in operation at Buxton since the autumn of 1886. It is situated near the gas works and sewage works. There are at present two cells side by side, but there is room for two more, in a building 52 ft. by 33 ft. by 25 ft. high. There is a high-level road to the top of the destructor, and a tramway from the firing floor, by which the clinkers are taken to a mortar mill worked by a water-wheel, the latter being used as well for stone breaking and sludge pressing. The chimney shaft is 145 feet high, and 4 ft. 6 ins. in diameter with a firebrick lining, and air space for 36 ft. The cost, as furnished to me in detail by Mr. J. Hague, Assoc. M. Inst. C.E., the surveyor to the local board, was,—

	£
Ironwork for two cells, &c. - - -	359
Brickwork to cells and building - - -	601
Chimney shaft - - - - -	543
Road - - - - - -	134
Mortar mill - - - - -	104
Sundries - - - - - -	94
	£1,835

During the winter months the fires were kept burning only by day, and in the summer the two cells are at present sufficient. One man is employed in feeding and clinkering. The working has been perfectly satisfactory and without complaint of smell or other nuisance, but the average cost of burning the refuse has not yet been arrived at.

Bournemouth.

A destructor of four cells side by side, covered by a corrugated iron shed, and having a chimney 137 ft. high, has lately been set to work at Bournemouth. The heat is utilized by being passed beneath a floor of iron plates 14 ft. long and 10 ft. wide, upon which the materials for tar-paving are heated. A bye-pass with dampers leads to the chamber under the iron floor, and cross baffle walls distribute the heat. The clinker and ashes amount to about one-third of the refuse burned, there being about twice as much clinker as ashes. They are used for the lower coat of tar-paving. Two men are employed by day and one by night.

In connexion with the destructor is a Jones' fume cremator, through which the products of combustion are passed before they enter the chimney.

Winchester.

A single cell has been built at the sewage pumping works at Winchester, having the flue connected with the chimney shaft of the steam boilers. It is enclosed in a neat brick building, and cost, including everything, 358*l.* It is attended to by a man who is also employed in connexion with other work close by, and it burns the worst of the house and the shop refuse, and fish offal: that part of the town refuse, in fact, which cannot be tipped without nuisance.

Fryer's destructors are also now in course of erection at Batley, Battersea, Longton, Salford (Broughton), and Hampstead.

Cost of Destructors,

The total cost at which destructors have been erected at the various places has been given, and it will be found to range from

400*l.* to 1,000*l.* per cell, the difference arising from the particular circumstances of each as regards site, cost of foundations, &c., and also from the amounts spent on roads, buildings, &c., and provision for future extension included in the cost of the destructor. Taking the furnaces alone, the cost may be stated at from 230*l.* to 250*l.* per cell, including ironwork, royalty, and brickwork, but excluding foundations.

and of burning refuse.

From the foregoing particulars of the Fryer's destructors in use in various towns it appears that, with ordinary working, a cell having a fire-grate area of 25 square feet will generally burn from 30 to 35 tons of refuse per week, equal to 22 lbs. per square foot of fire grate per hour, leaving a residue of clinker amounting generally to from one-quarter to one-third of the weight of refuse put into the furnace; both the quantity burned and the quantity of clinker remaining depending on the nature of the material. The cost at which the refuse is disposed of when delivered at the destructor has been given wherever the information could be obtained, but it must be borne in mind that no account has been taken of the saving effected in carting to the destructor instead of to distant tips, which is often as much as the cost of burning. The latter, it will be seen, varies a good deal, and depends mainly on the extent to which the heat from the furnaces is utilized in mortar making or otherwise. It is stated on the authority of Mr. J. Cartwright,[*] M.Inst. C.E., of Bury, that an 8 indicated horse-power engine can be effectively worked for 20 hours with the steam generated from burning 16 tons of refuse per day, a ton of refuse burned thus producing half an indicated horse-power per day. Mr. W. B. G. Bennett, M.Inst. C.E.,[†] estimates that a ton of the ash-bin contents at Southampton give something like $1\frac{1}{5}$ horse-power. From the details which have been given of the various destructors in use, it will be seen that, taking the lower result, in very few places is anything like the whole of the power generated utilized. Hitherto the power obtained has been chiefly used for grinding the clinker and making mortar, and where, as at Bolton, there is a good sale for mortar, the total cost of disposing of the refuse is reduced to a very small sum, although there perhaps nearly half the heat of the destructor goes to waste. At Warrington the heat appears to be well applied in drying and evaporating pail contents, and at Southampton power for raising sewage effluent and sludge by Shone's ejectors is obtained entirely from the destructor, a large proportion of the heat being made available. At Ealing a considerable proportion of the steam power is utilized in connexion with the sewage works. At Batley the heat from a destructor in course of erection will supply steam for a sewage pumping engine. The lifting of sewage, especially when Shone's ejectors or hydraulic engines, to which power is transmitted from a distance are used, is a purpose to which the heat from destructors might not unfrequently be applied. Electric lighting, as at Nottingham, is a means of utilizing the heat at night, but not by day, unless storage of power be resorted to. The generation of electric power appears to offer another opening for the application of heat from burning refuse.

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[*] Minutes of Proceedings of the Inst. C.E., Vol. lxxxviii., p. 181.

[†] Ibid, p. 207.

Among other furnaces invented, and in some instances patented, the following are or have been recently in actual use, with more or less success.

Healey's furnace.

Healey's destructor furnace was originally a modification of Fryer's. The advantages claimed were, less cost in construction and a more perfect consumption of fumes and vapours. The reverberatory arch, instead of being solid, was built of grooved and tongued firebrick lumps, and the gases passed by an opening at the back end of it through a hot chamber over the furnace and down by side flues at the front, and back again to the main flue under the drying hearth. Four cells, on this plan were erected at Southfield Lane, Bradford, in 1883, in connexion with an existing chimney 105 feet high, and continued in use until the end of 1885, in which year 5,300 tons of refuse were burned in them, equal to 25½ tons per cell per week, with a fire-grate area rather larger than in Fryer's destructor. The cost of the furnaces, exclusive of the chimney and the site, was 1,077*l.* The cost of working for the year 1885, including labour, repairs, coal, gas, rates, and taxes, but not interest and repayment for first cost, was 211*l.* 19*s.* 4*d.*, equal to about 9½*d.* per ton of material burned. In consequence of complaints of smell from the chimneys of both Healey's and Fryer's destructors, alterations were made in the former under the superintendence of the inventor. Drying chambers of iron plates were introduced over the furnaces, and the gases from one fire were passed over the next fire before entering the main flue. The small flues made for this purpose checked the draught, and the drying chambers were abandoned and openings were made direct into the main flue at one side of the back of the furnace, as in Fryer's destructor, which the Southfield Lane furnaces now resemble.

The use of the furnaces was discontinued in August, 1886, in consequence of a tip for the refuse being available, but they are now again at work. Mr. Healey has devised another furnace, called the "Economic Refuse Cremator," but it does not seem to have been tried anywhere.

Beehive destructor.

A furnace, called from its shape the "Beehive destructor," the invention of Mr. Stafford, Assoc. M.Inst. C.E., borough engineer of Burnley, has been tried at Burnley, Bradford, Batley, Leicester, and Richmond. It is circular, 6 ft. in diameter, with two fire-grates, one over the other, and a hearth covered with water below. The lower furnace is lighted up with coal and coke, and when it is well alight, the refuse to be burned is fed into the upper furnace. At Burnley it is still in use, burning shop and market refuse at night three times a week. About 3 cwt. of coal and coke is used to start with, and about 2 tons of shop refuse is burned in about 5 hours twice in the week, and 4½ tons of shop and market refuse on Saturday night in about 12 hours. The refuse appeared to be light and easily burned when dry, and the cinder and ashes proved to be a very small proportion of the quantity burned. At other places similar furnaces have not been successful. At Bradford, one was abandoned after three months trial on account of the cost of the fuel required for working it. At Batley, where a trial was made with about 52 tons of ordinary ash-pit and privy refuse, 6 tons 18 cwt. of coal and coke were used, and the cost of burning was 2*s.* 9*d.* per ton, of which 1*s.* 2½*d.* per ton was for fuel. The chimney was 120 feet high, with a good draught, but the refuse was not thoroughly burned, and very little clinker was produced. The destructor was abandoned after a fortnight's trial. At Leicester, five trials were made by Mr. Gordon, M. Inst. C.E., the borough engineer, in September and October, 1884, in which 100½ tons of ordinary ash-pit refuse were burned with the aid of 7¼ tons of coal and coke in varying proportions. The ashes remaining weighed 56½ tons, and the cost of burning, including coal, coke, and labour, was 2*s.* 2*d.* per ton of refuse. The chimney with which the destructor was connected was 160 feet high with a good draught. The furnace was considered a failure and abandoned. At Richmond (Surrey), two cells and a chimney 90 ft. high were erected in 1884. Complaints were at once made of smoke, effluvia, dust, and partially burned paper and other refuse matter escaping from the chimney and falling in the neighbourhood. Grids were fixed in the flue and in the chimney, and baffle plates were fixed to throw the products of combustion downwards into running water in the chimney base. By these means the draught was checked, so that the quantity burned was reduced by nearly one-third, while the nuisance from dust and effluvia was not abated, though the unconsumed particles of paper and refuse were smaller in size. Litigation ensued, and the use of the apparatus was stopped, not, however, before the original furnace had been re-built in a modified form, and a smoke consuming chamber with two fire-grates in which breeze was burned, had been added by Mr. Brooke, Assoc. M. Inst. C.E., the surveyor, with some promise of a better result.

At Batley, Leicester, and Richmond the bars of the upper fire-grates very quickly burned away.

Nelson destroyer.

The "Nelson Town Refuse Destroyer" was patented in 1885, by Messrs. Richmond and Birtwistle. As now in operation at Nelson, there are three furnaces placed side by side consisting of horizontal fire-grates 3 ft. wide and 3 ft. 6 ins. long, separated from each other by side walls, but communicating at the back with one drying hearth. For the purpose of experiment apparently, the hearth is differently constructed opposite each furnace. Opposite the first it slopes from the back to the fire-bars, and has apertures under iron shelf plates to admit heated air to the drying refuse. Opposite the second it is of fire-brick and level with the fire-grate, and opposite the third it is sloping like the first, but of solid fire-brick. There are passages in the side walls of each furnace for the purpose of admitting air heated by passing through the walls to different parts of the furnaces. They open just above the fire-bars and are intended to promote the combustion both of the refuse and of the vapours. The refuse is fed into openings at the back, and slides forward on the drying hearths to the fire-grates, the products of combustion passing from the furnaces transversely over the refuse on the hearth, which constitutes as it were a part of the main flue. The middle hearth, which is level and forms a hollow between two inclined hearths, is intended for wet garbage, slaughter-house refuse, and excreta mixed with ashes.

After leaving the furnaces the gases are passed over a coke fire on a fire-brick hearth, fed from above, and supplied with air through flues opening on a level with the hearth. All smoke and vapours appear to be effectually consumed, and the chimney which was then 18 yards high did not emit any smoke at the time of my visit in December 1886.

In a trial extending over two weeks in July, 1886, when 35½ tons of ash-pit refuse, and 6¾ tons of market refuse and garbage were burned, the cost was found to be, for the labour of two men 2*s.* 9*d.* per ton, and for the coke furnace 1*s.* 9*d.* per ton, and the residue after burning was 14½ tons of fine ashes and 9 tons of clinker, together more than half the refuse. The quantity burned compared with the grate-area does not seem to have been more than one-half of what Fryer's and other furnaces burn, and the large amount of ashes shows that the burning was imperfect. From August 6 to December 11, 1886, 187 loads were burned at a less cost for labour, and about the same for the coke furnace, with much less residue for ashes and cinders. The use of the apparatus was then discontinued on account of expense. The chimney has since been raised 10 yards, and with an increased draught a better result is hoped for.

It appears unnecessary to give any account of inventions which have not been tested by actual use, or which having been tried have been long since abandoned.

Boiler furnaces.

The burning of screened or selected refuse under steam boilers has been already mentioned as being in practice at Manchester, Bolton, Glasgow, and Birmingham. At the three first-named places, large grate area, a thin fire, and frequent clinkering and firing are depended on, but at Birmingham there are special arrangements which deserve notice. At the Montague Street Wharf, where by far the larger part of the refuse is burned under boilers to raise steam for drying excreta, there are 13 multitubular boilers, 11 of them 13 ft. long, and two 11 ft. long, and all 6 ft. 6 ins. in diameter. They have fire-grates 5 ft. wide, and 5 ft. 6 ins. long, fitted with patent lifting and moving fire-bars designed to break up the fire and prevent clinker forming in large cakes, and to keep the spaces between the bars clear. The play of the bars can be regulated to suit the kind of refuse burning, or it can be stopped entirely. The effect when in use is to work the clinker to the back, where it falls over the end of the fire grate, and is removed when cool from the ash-pit. The refuse burned under these boilers is that from which the fine ashes have been screened for mixing with excreta, and there is no difficulty in maintaining steam at a sufficient pressure to be used for drying excreta. There are besides, two Galloway boilers, 27 ft. 6 ins. long and 7 ft. 6 ins. diameter, fed with cinders screened from the refuse and mixed with slack, which raise steam for two 25 horse-power engines which drive the machinery of the yard.

The Carbonizer.

A furnace called a "Carbonizer," for the purpose of converting vegetable refuse into charcoal, has been erected at Leeds, Birmingham, Warrington, and Derby, and is in use in the last-named town. It consists of a group of four cells of brickwork, each 2 ft. by 3 ft. 6 ins., and 13 ft. high, with a vertical flue in the middle, and a furnace alongside each cell at the bottom. Within the cells a series of cast-iron plates are fixed with their upper edges touching the walls and their lower edges standing away, forming a continuous sloping ledge winding round the cell from the top to near the bottom. where they terminate in a fire-brick chamber having a sliding door in the bottom. The refuse is fed in at the top and is not mobile enough to rise behind the plates, so that a spiral flue is left for the passage of the hot gases from the furnace at the bottom to an opening into the vertical flue at the top and downwards to the chimney. The refuse dries and sinks, coming into contact with hotter plates as it descends until it reaches the red-hot fire-brick chamber. No air reaches the refuse except through the furnace, and it is therefore charred and not burned. At intervals the sliding door in the bottom is opened and a charge of charcoal is withdrawn. Each cell carbonizes about two tons of refuse in 24 hours. The furnace burns cinders selected from the ash-pit contents. The charcoal is cooled in a revolving cylinder on which a stream of water flows, and is sifted through a screen at the end in a fine powder. At Derby the carbonizer cost 1,000*l.*; it is worked about two days a week at a cost of 18*l.* per year, and produces about 20 tons of charcoal a year, a ton of vegetable refuse, sawdust, &c. yielding a cwt. of charcoal, which is used for deodorizing, and is valued at 5*l.* per ton.

At Leeds no use or market was found for the charcoal and analysis proved it to contain 80 per cent. of earth.

Dust from chimneys.

Although experience has shown that town refuse can be effectually burned in destructors and other furnaces without causing nuisance or offence at or about the works themselves, there are two points about which complaints have arisen. One is of a fine dust, and sometimes of charred paper, proceeding from the chimney and falling at some little distance off. The quantity of dust produced from the burning refuse appears to vary a good deal in different places, and the amount of it which is carried into the flue and up the chimney depends to a considerable extent upon the care with which the excessive draught in the high chimney is regulated by dampers. At one destructor about 2 cubic yards per cell per week was said to be removed from the dust chamber, but a more usual quantity is

$\frac{1}{4}$ to $\frac{1}{2}$ cubic yard. A sample of flue dust from the Armley Road destructor was found on incineration by Mr. F. N. Sutton, to consist of 93·6 per cent. of mineral matter, and 6·2 of organic matter, the rest being moisture imbibed in transit. The mineral matter under the microscope appears to be ash and glassy slag, with many fragments of what seem to be filaments of glass, probably melted in the furnaces, and drawn out by the draught. It is not likely that in all flue-dust the organic matter is so completely burned as in this sample.

In the destructors more recently erected the main flue has been enlarged beneath the cells to form a chamber, in which, the velocity being checked, the dust may fall. Instead of a flue 4 ft. wide, as in the earlier destructors, there is now a chamber 10 ft. wide and 8 ft. high, and with good effect. Sunk channels have been formed on each side of the bottom of the chamber to collect the dust, and low cross walls for the same purpose have been tried. The latter must be built of dry bricks in the middle to be pulled down when the flue requires cleaning, or, preferably, there may be, as at Salford, a removable iron plate to close an opening wide enough for a wheelbarrow. Frequent removal of the dust is very necessary to prevent its being carried up the chimney. The larger particles, such as charred paper, have been arrested by wirework screens or grids. At Derby charred paper was stopped by two baffles or bridges in the flue a short distance apart, one at the bottom and the other at the top. The best preventatives, however, appear to be large dust chambers, proper regulation of the draught, and frequent removal of the dust.

Smell from chimneys.

The other ground of complaint is an offensive smell from the chimney. In some instances it is true that the smells complained of did not proceed from the furnaces at all, but it cannot be denied that the smoke and vapour from furnaces burning town refuse have often an offensive smell which, under certain conditions of the atmosphere, can be recognised at some distance on the leeward side of the chimney.

Dr. Odling, in a report to the Bradford Corporation, rightly, I think, attributes it to empyreumatic vapours given off when the refuse begins to burn before it reaches the hot fire, and is undergoing destructive distillation or frizzling. When, as in the Manchester and Birmingham furnaces, the fresh charge of damp refuse is thrown directly into the hot fire, this action must go on, and the arrangement in Fryer's destructor for feeding from the back of the furnace, while partially drying the refuse, affords a direct passage into the flue for vapours arising in the cooler part of the furnace.

The products of combustion must of course vary with the nature of the material burned, but a good deal more depends upon the rate at which it is burned, and the care and regularity with which the furnaces are fed and clinkered. Smoke, and imperfect combustion, follow any attempt to overload the furnaces, and this is especially the case when the refuse is unusually wet. Where there are many cells or furnaces, by careful and systematic firing and clinkering the gases from the recently charged and cooler fires may be made to mingle in the dust chamber or flue with those from the hotter fires, and a temperature may be obtained high enough to destroy offensive vapours that escape from the furnaces. The care with which firing and clinkering is regulated at Manchester and Leeds has been mentioned, and it might be followed with advantage in other places.

To effect the combustion of offensive vapours it has been suggested that the gases from the furnaces should be passed through or over another fire. The destruction of smell by passing the vapours from the excreta dryers over the fires of the Birmingham refuse furnaces has been mentioned, and it is still more strikingly exemplified at the Rochdale works, where there is a special furnace for the purpose, through which the vapours from the drying cylinders are forced by a blower after having been passed through condensers. The furnace devised by Mr. Charles Jones in connexion with the Ealing destructor has been described. As patented, the fume cremator differs from that erected at Ealing in being circular in cross section, and one of this form was added to the Blackburn destructor. The fire-grate is broken up into six strips 9 ins. wide and 2 ft. long, separated by 9 ins. of hearth, and the actual grate area is only 9 sq. ft. compared with 20 sq. ft. at Ealing for the same number of cells. The fire occupies a width of 2 ft. at the bottom of a cylindrical furnace 3 ft. 6 ins. in diameter, instead of a width of 4 ft. in a furnace 3 ft. high. The cremator is badly placed, and there are unfortunate throttlings of the draught. The effect of the cremator was, it is stated, to reduce the draught by one-fifth, and the quantity of refuse burned from 108 tons to 77 tons per week, while the consumption of coke was 8 tons per week, and the cost of working was increased at the rate of 200*l.* a year, which included an attendant at 30*s.* a week, and the coke at 5*s.* 10*d.* per ton. Its use has been discontinued on account of the expense of working.

The fume cremator.

At Bournemouth the cylindrical form has been repeated, but there is no throttling of the draught. It is proposed to burn cinders screened from the refuse instead of coke breeze in the cremator.

A separate furnace in which the vapours are burned is likewise a feature in the Nelson destroyer, and appears to effectually answer the purpose of consuming the smoke and vapours.

Washing the gases by water spray has been proposed as a means of depriving them both of the fine dust and the offensive vapours. It would, by lowering the temperature, seriously diminish the draught unless the latter were maintained by other means. A closed ash-pit, with a forced draught by means of a blower or a fan, as in use at Glasgow, or a steam jet or an exhaust fan in connexion with the chimney might perhaps be applied to maintain a draught sufficient for proper combustion. In the destructors at present in work there is generally sufficient surplus heating power to provide a forced draught, but any power applied to that purpose would, of course, be no longer available for other more remunerative work.

Experiments and observations.

Temperatures.

It appeared to be desirable to get further insight into the process of combustion in furnaces burning town refuse, and I am indebted to Mr. A. E. Fletcher, the Chief Inspector under the Alkali Acts, for the valuable help of his assistant, Mr. F. N. Sutton, in making experiments for that purpose. Observations were made on the temperatures and composition of the products of combustion, and the speed at which they pass off, at Whitechapel, Ealing, and Bradford. The temperatures were taken with Siemens' water pyrometer, those of the different cells being taken in the flue leading downwards to the dust chamber, as giving a fairer result than any position within the cell itself, where high temperatures are to be expected at points when combustion is active. As might be expected they were found to vary a good deal, according to the condition of the fires. At the Whitechapel destructor the temperatures on July 6th, 1887, ranged from 180° to 1,000° Fahr., the average of the eight cells being 490°. The highest temperature observed was about 20 minutes after the fire had been clinkered, and the lowest when a charge, largely composed of damp vegetable refuse, had recently been drawn down on to the fire. A dead fire ready to be clinkered gave off gases at 290°–300°. Some cold air was admitted into the flue while the pyrometer heater was in it, so that something under the usual temperature may have been recorded. Any error from this source was avoided in subsequent experiments. Three trials of the temperature in the main flue between the destructor and the chimney shaft, at about 40 feet from the former, gave 410°, 540°, and 410° at intervals of about 20 minutes. The material being burned, owing to the season of the year, contained a very large proportion of green vegetable refuse, and but little cinders and ashes, and was probably as bad a sample for burning as ever comes to the destructor. The feeding and clinkering of the furnaces was being carried on as usual, one furnace being clinkered every 10 minutes, until all were clinkered, and there being then an interval of half an hour, when the process was repeated; the furnaces being taken, not in rotation, but in the order in which they needed clinkering. It may, perhaps, be doubted if the lower temperatures at which the burnt gases escaped from the cells are sufficient for the perfect destruction of contagia and virus, but the mean temperature reached in the dust chamber, where gases from all the cells mingle, would be enough to deprive the small particles passing off of any infectious properties they might possess.

At the Ealing destructor, burning the mixture of sewage sludge and refuse already described, and house-refuse, in about equal proportions, the temperatures observed in the flues leading from three cells were 855°, 520°, and 520°. The fourth flue could not be conveniently got at, but, judging from the fire, the temperature was probably about the same as in the second and third. The temperature of the gases after leaving the destructor and before entering the cremator, was, when the fires were all dead and requiring clinkering, 445°; at other times temperatures of 565° and 625° were observed; and with three fires in good condition, and the fourth moderately good, the temperature was 700°.

No great increase in the temperature of the gases, after passing through the fume cremator, was observed on this occasion, and the heat in the cremator, taken at about eight inches above the coke fire, did not exceed 700°. At a later visit, when the second analysis given in the tables below was taken, there was a hotter fire in the cremator, and the gases passing from the destructor at 675° had a temperature of 880° on leaving the cremator, the heat three inches above the coke fire in the latter being 970°. The mixture of sludge and refuse was then being burned without any other refuse.

At Bradford, the temperatures of the gases from the six cells of one block of the destructor, ranged from 270° to 730°, the mean of the whole being 480°. The observations were all made soon after the fires had been clinkered and fed, the lowest result being from a cell which was fed while the heater was in the flue, with wet midden and green vegetable refuse. Observations taken in the main flue leading from the six cells to the chimney an hour before and three hours after gave a temperature of 415°.

At Armley Road, Leeds, observations were made in the main flue between the destructor and the boiler, to compare the readings of the Siemens' water pyrometer with those of a pyrometer by Casartelli, composed of tubes of different metals. The Siemens' instrument gave temperatures of 580° and 650°, when the Casartelli pyrometer indicated 570° and 670° not far off, a sufficiently close agreement. Pyrometers are now fitted in the main flues of both the Leeds destructors, and registers are kept of their readings, which cannot fail to promote careful clinkering and feeding. The average heat for the day at the Armley destructor appears from the register to be from 530° to 540°, ranging from 350° or 400° on Monday mornings (the fires having been banked on Sunday) to 650° or 670° in the afternoons. These good results are, no doubt, due as much to the regularity with which the cells of the destructor are fed and clinkered as to the venetian fire-bars with which the furnaces are fitted.

The foregoing observations appear to show that the temperature generally reached in refuse furnaces has been exaggerated.

Volume of air entering furnaces.

To ascertain the volume of the gases passing off, and thence to deduce the proportion of the air entering the furnaces to the refuse burned, it was necessary to measure the speed of the gases in the main flue or chimney. This was done by Mr. Fletcher's anemometer, and also by a ready method previously adopted by me, whereby the time taken by a puff of fine dust in passing up the chimney of known height was measured. The results obtained by the two methods agreed fairly well, giving the velocities of the hot gases as from 10 to 15 feet per second. The speed and temperature of the hot gases being ascertained, and the area of the flue being known, after allowing for the aqueous vapour passing off, the volume of air entering the furnaces could be deduced with tolerable accuracy. The quantity of refuse being burned could only be estimated, by taking the daily average quantity, and this renders the results obtained only approximately accurate. Without entering into details it is sufficient to state that the air entering the furnaces appeared to be about 8½ tons to a ton of refuse burned at the Armley Road destructor, Leeds, about 9¼ tons of air to a ton of refuse at Whitechapel, and about 13 tons of air to a ton of refuse at Bradford.

It is instructive to compare these results with the proportion of air to fuel of a better quality.

For the complete conversion of a ton of carbon into carbonic acid, the oxygen of 12·2 tons of air is required. In practice at least one-half more is necessary, and in ordinary boiler-furnaces nearly double this quantity of air is used for perfect combustion of coal. The air entering a furnace burning town refuse appears from the above experiments to be less than, or not much to exceed, the theoretical quantity required to convert the refuse into carbonic acid, supposing it to be all carbon; or about one-third to one-half what is required for the complete combustion of coal containing about 80 per cent. of carbon in an ordinary boiler furnace. But we know that the refuse contains comparatively little combustible matter. Instead of leaving 4 to 8 per cent. of cinder and ashes as coal does, it leaves 25 to 33 per cent., and it contains besides a large proportion of moisture. To get a definite idea of what the proportion of the latter is, some experiments have been made for me by Mr. Cox, Mr. Newhouse, and Mr. La Riviere. Vessels containing samples of refuse were placed in the main flue or chimney base, and thoroughly dried with proper precautions, and the loss of weight was ascertained. The trials were all made in October 1887, and results are shown in the following table:—

Proportion of moisture in refuse.

Description of Refuse.	Loss of Water in Drying.	——
Bradford.—Average ash-pit refuse, neither very wet nor very dry.	47 per cent.	Mean of 10 trials with 324 lbs. of refuse. Material charred.
Leeds.—Dry ashes, privy-midden refuse, vegetable and animal matter, as taken from the platform.	39 „	Mean of 2 trials with 124½ lbs. of refuse.
Leeds.—Dry ash-pit refuse	31 „	Trial on 60 lbs.
Leeds.—Privy-midden refuse	33 „	Trial on 60 lbs.
Whitechapel.—Average refuse	29½ „	Mean of 6 trials on 101 lbs. of refuse.
Vegetable refuse.—Bradford	51 „	Trial on 17½ lbs.
Fish refuse.—Bradford	82 „	Trial on 33 lbs.
Garbage.—Leeds	93 „	Trial on 8 lbs.

The ordinary ash-pit refuse of Bradford, which is found to contain 47 per cent. of water, leaves 33 per cent. of clinker and ashes, so that not more than 20 per cent. of the whole can be actually burned; and the 13 tons of air to a ton of refuse is 65 tons of air to a ton of fuel burned.

Similarly, at Leeds, the 39 per cent. of water and 33 per cent. of cinders and ashes leave not more than 28 per cent. combustible, and the proportion of air to the fuel burned is more than 30 tons to a ton. At Whitechapel, when the air was measured in July, the moisture in the refuse was far greater than in October, and the proportion of air to refuse was probably between the two just given.

Analyses of escaping gases.

The results of analyses of gases taken from the main flue are given in the tables below. Two analyses of gases from the Leeds destructors, which are given in a report by Mr. T. Fairley, the borough analyst, are added to those made by Mr. F. N. Sutton. In a second table the oxygen and nitrogen are stated as common air and nitrogen, that being the condition in which they pass off.

ANALYSES OF GASES FROM DESTRUCTOR FURNACES.

—	White-chapel.	Ealing (1).	Ealing (2).	Bradford (1).	Bradford (2).	Leeds, Armley.	Leeds, Burmantofts.
Carbonic oxide -	1·00	0·70	0·15	0·00	0·00	0·00	0·00
Carbonic acid -	2·54	1·00	2·20	1·60	2·40	2·32	1·24
Oxygen - -	17·55	18·20	18·20	18·70	18·00	17·42	18·11
Nitrogen - -	78·91	80·10	79·45	79·70	79·60	80·26	80·65
Volumes -	100·00	100·00	100·00	100·00	100·00	100·00	100·00

THE SAME ANALYSES OTHERWISE STATED.

—	White-chapel.	Ealing (1).	Ealing (2).	Bradford (1).	Bradford (2).	Leeds, Armley.	Leeds, Burmantofts.
Carbonic oxide -	1·00	0·70	0·15	0·00	0·00	0·00	0·00
Carbonic acid -	2·54	1·00	2·20	1·60	2·40	2·32	1·24
Air - -	83·57	86·66	86·66	89·05	85·71	82·95	86·24
Nitrogen - -	12·89	11·64	10·99	9·35	11·89	14·73	12·52
Volumes	100·00	100·00	100·00	100·00	100·00	100·00	100·00

It will be observed that in the first table the volume of nitrogen is nearly the same in all the analyses, and represents the 79 per cent. of nitrogen in the air that passes into the furnace. The 21 per cent. of oxygen in the air entering the furnace is represented by the unconsumed oxygen, by the per-centage of carbonic acid (which is equal in volume to the oxygen combined in it), and where there is carbonic oxide by half the volume of that gas. A small proportion of the oxygen may also combine with any hydrogen there may be in the fuel, and pass off as aqueous vapour.

The small amount of carbonic acid must be noticed, ranging from 1 to 2½ per cent. The proportion in the gases from an ordinary steam boiler is 7 or 8 per cent., and sometimes as much as 10 per cent., when the air entering the furnace is double the quantity required for the combustion of the fuel, and about 10 per cent. of the oxygen remains. The air passing off unburned amounts in these analyses to 83 or 89 per cent., instead of being 50 per cent. as it would be if all the fuel in the refuse were burned with double the quantity of air necessary for its combustion. A good deal of air is admitted through the fire-doors while clinkering and drawing down the refuse is going on, but when all the doors were kept shut, as they were when the samples from Ealing and the second sample from Bradford were taken, the proportion of air passing off unburned amounts to 86 per cent. This is due, no doubt, to the irregular distribution of the small proportion of combustible matter among the refuse, and its damp state, causing a large quantity of the air to pass through without coming into contact with fuel ready for combustion.

The presence of carbonic oxide in the samples from the Whitechapel and Ealing destructors shows that, notwithstanding the large excess of air, combustion was imperfect. At Whitechapel the refuse being burned was largely composed of green vegetable waste, and at Ealing the mixture of sewage sludge and ash-pit refuse with about an equal quantity of house refuse, was being burned on the first occasion, and on the second the mixture of sludge and ash-pit refuse only. The carbonic oxide did not appear to be burned in the fume cremator. The gases from the latter contained, as much as 2·1 per cent. of carbonic oxide, besides 3·8 per cent. of carbonic acid in a sample analysed on the first occasion, but the composition of the gases entering at the same time was not then ascertained. On the second occasion, samples were taken at the same time of the gases before and after they passed through the cremator, and yielded the following analyses:—

——	From Destructor.	From Cremator.		
Carbonic Oxide - -	·15	·20		
Carbonic Acid - -	2·20	4·60		
Oxygen - - -	18·20	16·00	=	air 76·2
Nitrogen - - -	79·45	79·20		nitrogen 19·0
Volumes -	100·00	100·00		

The supply of air to the fume cremator through the ash-pit was shut off while these samples were being taken, to prevent the dilution of the gases under examination with outside air, the unconsumed oxygen in the gases from the destructor being depended on to carry on the combustion in the cremator. The analysis, however, shows that the coke fire was giving off carbonic oxide, in consequence of an insufficient supply of oxygen. The temperature was somewhat lowered by shutting off the air from the cremator, but when the flues were open, and the fire was burning well, the temperature 3 inches above it was but 970°, so that the temperature required for the combustion of carbonic oxide, about 1,100°, was not reached except in actual contact with the burning coke. The gases were, however, heated from 675° to 880° in passing over the fire, and all smoke and vapours appeared to be burned.*

Aqueous vapour.

An important constituent of the escaping gases does not appear in these analyses, namely, the aqueous vapour, of which 27 cubic feet at 212° are evaporated from every pound of water in the refuse. In the samples when analysed the vapour has again been condensed, and so escapes observation. The 27 cubic feet for each pound of water are expanded by heat to 30 or 40 cubic feet as they pass off mingled with the products of combustion. Thus the vapour given off from the 47 per cent. of water in the Bradford refuse amounts to 97,000 cubic feet per hour, equal to upwards of 5 per cent. of the total gases measured as they passed off at a temperature of about 300°. At Whitechapel in July the proportion appeared to be as great.

It seems likely that the aqueous vapour has a good deal to do with rendering evident the small proportion of offensive vapours in the products of combustion. It must be intimately mingled with the latter at high temperatures, and in cooling below 212° it must be condensed and reduced to its original bulk in the watery particles of what is commonly called steam. The empyreumatic vapours are probably filtered out from the bulk of the escaping gases by the condensing steam, attaching themselves as an oily film to the watery particles, in the same way as the products from coal-burning condense on the watery spherules of fog or cloud.† Further condensation may follow from the watery particles coalescing, or being again evaporated and absorbed as the degree of saturation of the surrounding air may determine. If the vapours be thus concentrated, instead of being dissipated in the air, a small proportion of them may give rise to the offensive smells complained of.

It may be owing to the condensation of the aqueous vapours in the aspirator by which the gases were drawn from the flue, thus carrying down the empyreumatic oils, that it was impossible to detect the presence of offensive vapours by smell in the gases analysed; an odour like burned paper, sometimes slightly tarry, being alone perceptible. No other means of testing their presence was taken by us; but Mr. Fairley, in his report on the gases from the Leeds destructors, states that they contain in minute quantities sulphurous and sulphuric acids, ammonia salts, volatile organic matter, and solid particles in suspension consisting of the finest flue dust. On an occasion when the gases at Burmantofts were thought to be more impure than usual, tests gave the following results stated in grains per 100 cubic feet:—

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* It is stated on the authority of Dr. Wanklyn that temperatures of 1,270° in the cremator, and 1,100° in the escaping gases have since been observed.

† *Vide* Dr. E. Frankland on Dry Fog. Proceedings of the Royal Society, Vol. XXVIII., p. 238.

Ammonia - - - -	0·1
Nitrogenous organic matter - -	0·6
Sulphurous and sulphuric acids -	18·0
Organic matter - - - -	7·0

The organic matter was thought by Mr. Fairley to be in part due to flue dust passing into the testing apparatus, and it would appear to include also the empyreumatic oils from imperfectly burned materials.

An attempt made by Mr. Rimington, the borough analyst of Bradford, to absorb in alcohol the substances causing offensive vapours in the gases from the Bradford destructor, resulted in the production of something which, when diluted, was in taste and smell not unlike Scotch whiskey.

Conclusions.

The large proportion of unconsumed air passing away from the furnaces, amounting, as the foregoing analyses show, to from 83 to 89 per cent. of the products of combustion, suggests the possibility of supplying air to a second furnace by that which has already passed through one fire. An alternating arrangement by which the unconsumed air and vapours from the dead fires of one furnace may be made to supply the clearer fire of another furnace appears possible as a means of destroying smoke and offensive vapours. There might be a difficulty in maintaining the draught without artificial aid, but the fan, as at Glasgow, or some other blower might be used. In a separate furnace like the fume cremator it would seem more effectual to pass the gases and vapours through, instead of over, the fire, and by suitable arrangements of dampers the gases might be directed either way, and fresh air might be admitted at will.

If it be true that the empyreumatic vapours which cause the nuisance are carried down by the condensation of the aqueous vapour, the thorough condensation of the latter before it passes up the chimney, would prevent the escape of offensive smells. Such a process is practicable, but the gases after being cooled would have to be re-heated, or other means would be necessary to maintain the draught, involving perhaps complications which it would be better to avoid.

The escape of dust and of smell from the chimney must be regarded as defects to be amended, especially where the air is not already polluted by factory chimneys. Much in the way of prevention may be effected by careful and systematic firing and feeding, combined with large flues or dust chambers, frequent removal of dust, and proper regulation of the draught. When these precautions do not suffice, passing the products of combustion through or over a second fire appears to be the most promising means of destroying smoke or smell and preventing the escape of dust.

In other respects the burning of town refuse by furnaces already in use appears to be successfully carried out. There is no accumulation of an offensive material at the works, and very little smell. Everything combustible is burned within a few hours of collection without nuisance, and at a cost which compares favourably with the old system of carting the refuse to tips. A valuable means is at the same time provided for effectually disposing of infected bedding and clothing, condemned meat and provisions, and the carcases of diseased animals. Further improvements may be expected, but the results already attained show that the destruction of the refuse of towns by fire is not only practicable, but is the best, and often the only way of dealing with it in a manner to satisfy sanitary requirements.

I have the honour to be,
Sir,
Your obedient Servant,
December 1887. THOMAS CODRINGTON.

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